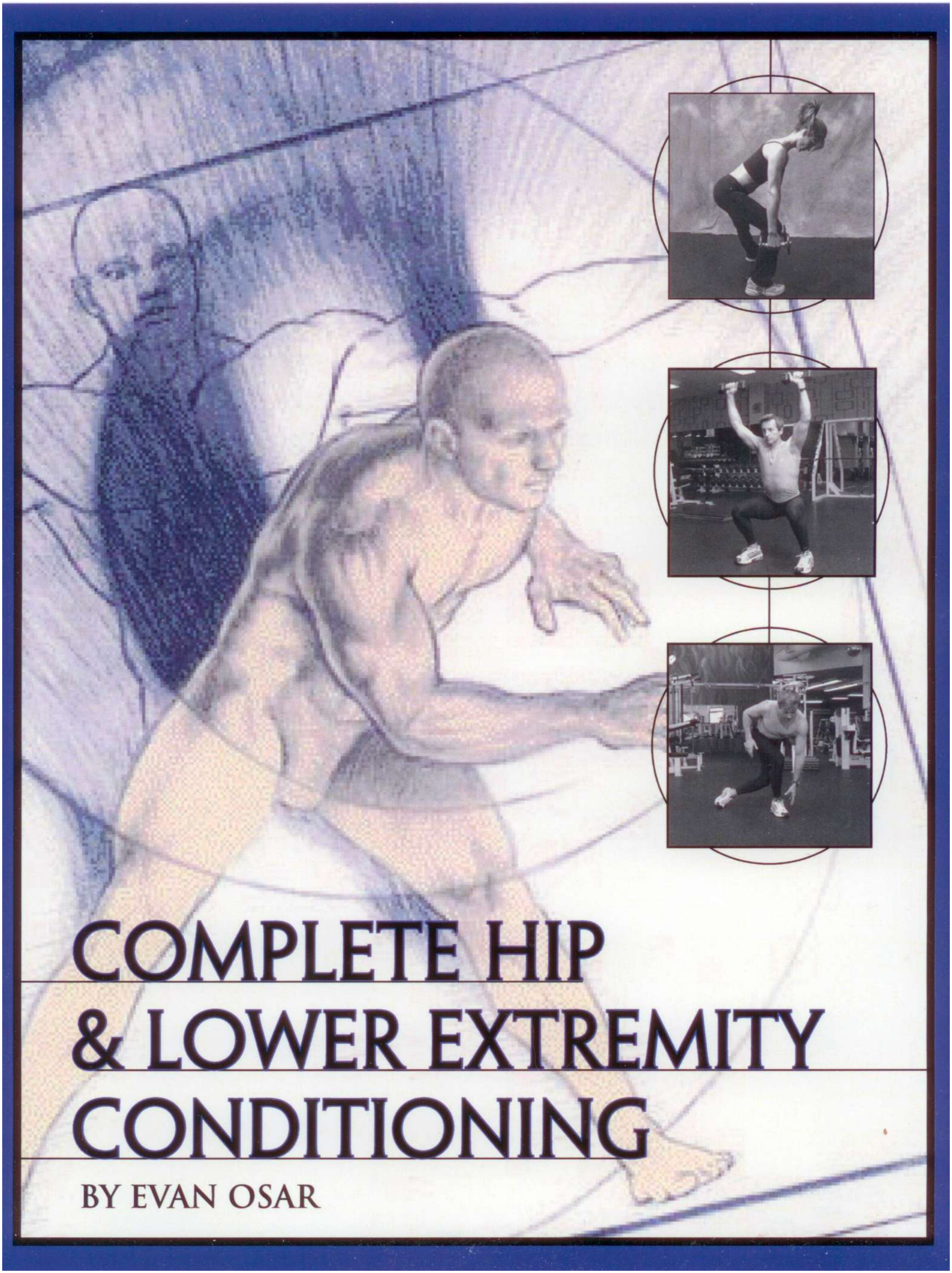


COMPLETE HIP & LOWER EXTREMITY CONDITIONING

BY EVAN OSAR

SET YOURSELF APART IN THE FIELD OF PERSONAL TRAINING AND PERFORMANCE ENHANCEMENT.

Visit www.fitnesseducationseminars to discover all of our seminars including the Annual Midwest Strength, Conditioning and Rehabilitation Symposium

Complete Hip and Lower Extremity Conditioning

Evan Osar, DC, CMT, PES, CSCS
Chiropractic Physician
Clinical Massage Therapist
Performance Enhancement Specialist
Certified Strength and Conditioning Specialist

Contributions from:

Shawn Allen, DC, DABCO
Chiropractic Physician
Diplomat American Board of Chiropractic Orthopedists

Illustrations
Scott Tallman
Chris Cismesia

Photography
John Martin-Eatinger
Jenice Mattek

Models
Danielle Davidson
Jenice Mattek
Evan Osar
Steven Schmoldt

Disclaimer

This text is intended to provide health care professionals with basic anatomy as it is related to motion and the basics of functional exercise. It is not intended to diagnose or treat any specific condition. The author is not responsible for any injury resulting from any of the material contained herein. Before beginning any exercise program, it is recommended that readers consult and obtain clearance from a licensed physician.

About The Authors

Dr. Evan Osar received his Bachelor of Science degree in Chiropractic from the Palmer College of Chiropractic. He has also received a diploma in clinical massage therapy from The Soma Institute - National School for Clinical Massage Therapy and national certifications from the National Academy of Sports Medicine and the National Strength and Conditioning Association.

Dr. Osar has dedicated himself to learning not only through self instruction but by instructing others. He holds a faculty position at The Soma Institute - National School for Clinical Massage Therapy where he teaches Kinesiology and Clinical Integration and has authored manuals on functional anatomy and core conditioning. Dr. Osar is one of the founding board members of the International Youth Conditioning Association. He has contributed a chapter on posture for the official textbook of the International Youth and Conditioning Association and has helped develop the Level 2 and 3 certifications. Additionally, he presents lectures for personal trainers and other health care practitioners. He is the developer of the Fast and Furious series of seminars focusing on complete core, hip and shoulder conditioning and is currently working on the third edition of Form and Function which he is co-authoring with Dr. Shawn Allen. He currently operates O.S.A.R. Consulting, which specializes in chiropractic orthopedics, sports medicine, athletic training and functional rehabilitation. In addition to his work with the public, Dr. Osar treats professional athletes and members of the Jofferey Ballet of Chicago and Zephyr dance companies.

Dr. Shawn Allen completed his undergraduate work in 1991 at the University of Waterloo in Ontario, Canada, where he obtained a Bachelor of Science degree with an emphasis on sports medicine from the Faculty of Applied Health Sciences. He also holds a Bachelor of Science degree in Human Biology.

Dr. Allen is a 1995 graduate of the National University of Health Sciences. During his 3 year in-house post-doctoral residency in chiropractic orthopedics he worked with some of the most respected doctors in the country in that field, may of whom now serve as staff at the world-renowned Texas Back Institute in Piano, Texas. There are only a few dozen chiropractors in the world who have completed this specialized residency program.

Dr. Allen is board certified by the **American Board of Chiropractic Orthopedists,** and credentialed as a **Fellow of the Academy of Chiropractic Orthopedists.** He is an active physician within the **American Academy of Spine Physicians** - a unique global organization of

dedicated spine care specialists (neurosurgeons and chiropractors) committed to conservative and cooperative care.

In December 2003 Dr. Allen completed his post-doctoral board examination qualifying him as a **Diplomate in Age Management Medicine (DABAAHP)** in the **American Academy of Anti-Aging Medicine** of which he is also a member. This complimented previously completed, extensive training at the prestigious **Cenegenics Medical Institute** in Las Vegas, considered by many to be the most successful and experienced Age Management practice in the world.

Dr. Allen is a member of the faculty at the **Lincoln School of Post-Graduate Education** where he has lectured nationally on orthopedics, sports injuries and rehabilitation. He has also taught pre-med anatomy at **Benedictine University** in Lisle, Illinois. After two years of teaching biomechanics, orthopedics and sports medicine at **National University,** he continues there as a guest lecturer in these specialties. During his most recent work at National University he has created and taught a course in Advanced Clinical Orthopedics with an emphasis on lower extremity-pelvic biomechanics and functional orthopedics.

Dr. Allen serves in several consultant and educator positions outside of the university. He is a lecturer and biomechanics/technical consultant for Sole Supports Inc. Gait and Biomechanics Lab and has lectured and provided orthopedic consultation at one of the largest MRI and imaging companies in the greater Chicago area. His expertise in examining, rendering opinions, diagnosing, and making treatment recommendations for unique cases is sought regularly by several area medical groups, physical trainers, physical therapists and chiropractors.

Dr. Allen also continues to book topic-specific lectures for corporate and private industry, small businesses, charitable groups and special interest groups. He is currently a treating physician for the prestigious Chicago Jofferey Ballet company.

Dr. Allen practices medicine out of **The Physician's Sports and Injury Center** in Westmont, Illinois, and is head consultant and president of **ALLEN CHIROPRACTIC ORTHOPEDICS.** His years of teaching and practice have encompassed orthopedics, sports injury assessment and care, rehabilitation, chiropractic, custom foot orthotic casting, fitting and modification, basic fracture management and performance sports biomechanics. He considers his expertise to be in conditions affecting the shoulder, wrist, hip, knee, foot and ankle as well as the neck and spine.

Dr. Allen is presently lecturing in the community on several health-related issues. Included are topics on age management medicine (disease prevention protocols), increasing awareness, prevention and management of sports related head injuries in youth and high school sports, and the abuse of performance related drugs and supplements in youth sports.

Table of Contents

INTRODUCTION

While structurally one of the simplest joints in the human body, functionally it is anything but simple. Ironically, the magnitude and complexity of the hip joint and its relation to low back and knee dysfunction often goes unnoticed in rehabilitation clinics. Likewise, the significance of the hip to generating power for athletic performance is often neglected often to the detriment of the athlete that is attempting to both generate and decelerate maximum force. This manual will introduce basic biomechanics of the hip, its relation to the pelvis and lower extremity in addition to a rationale for functional training and conditioning of the entire hip complex.

The hip joint is a classic example of a ball and joint articulation responsible for providing the lower extremity not only with a significant degree of mobility but, more importantly, a high degree of dynamic stability. It derives its stability from several sources, most notably the depth of the acetabulum (hip socket) and the presence of the acetabular labrum, a fibrocartilaginous attachment surrounding the rim of the fossa. The hip joint is enclosed by a joint capsule that surrounds the articular surfaces and spans approximately to the neck of the femur. The joint capsule blends with several strong ligaments that add passive stability to the hip joint. These include the iliofemoral, pubofemoral and ischiofemoral ligaments (see below). All three ligaments are vital in stabilizing and preventing excessive hip extension while simultaneously limiting hip abduction (Magee).

- **Iliofemoral ligament:** The iliofemoral ligament lies in an inverted Y-position attaching from the anterior inferior iliac spine and then dividing to attach distally to the superior and inferior aspects of the intertrochanteric line (in between the greater and lesser trochanters of the femur). It is the strongest ligament in the body.
- **Pubofemoral ligament:** The pubofemoral ligament extends from the superior pubic ramus of the pubic bone to attach laterally on the anterior aspect of the intertrochanteric line.
- **Ischiofemoral ligament:** The ischiofemoral ligament originates from the ischium just posterior to the acetabulum then wraps over the femoral neck to attach to the trochanteric fossa. This ligament assists in controlling internal rotation of the hip (Lee).

Other ligaments that add minimal support to the hip include the femoral arcuate ligaments and the two located within the joint, the ligamentum teres and the transverse acetabular ligaments.

Muscles of the Hip

The forces placed upon the hip during many routine activities can be formidable. Various muscle and fascial attachments work to provide both the static and dynamic stability needed by the hip. For example, standing on one leg increases the weight on the hip by two and half times body weight, while walking up stairs increases it by three times. On the other hand, running may result in forces exceeding four and a half times one's body weight. These forces are aptly dealt with by the many muscles that cross and attach to the hip joint. There are numerous muscles attaching directly to the hip joint that add dynamic stabilization to the hip including the psoas major, iliacus, gluteus minimus and medius, obturator externus, obturator internus, gemellus superior, gemellus inferior and piriformis. While not directly attaching to the hip joint, several additional muscles including the quadratus femoris, rectus femoris, sartorius, adductor complex, hamstrings, tensor fascia latae and gluteus maximus significantly influence hip function nonetheless.

There is a similar muscular pattern between the local and global muscle systems of the hip and shoulder regions. Below is a comparison between the 2 regions.

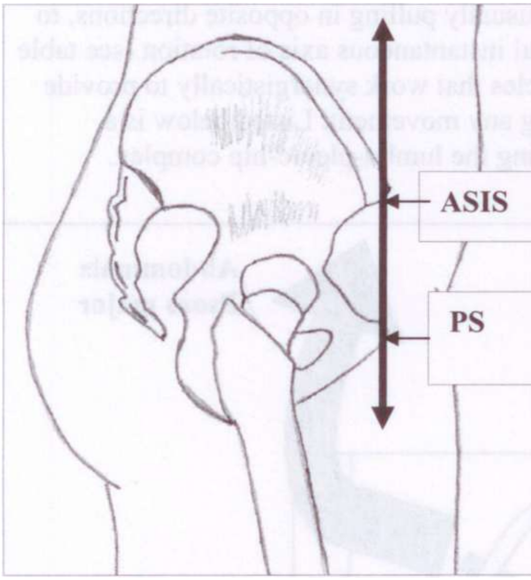
	DELTOID	**HIP**
Global muscle system (deltoid)	Anterior deltoid Middle deltoid Posterior deltoid	Tensor fascia latae Gluteus medius Gluteus maximus
Local muscle system (rotator cuff)	Suprspinatus Infraspinatus Teres minor Subscapularis	Gluteus minimus Piriformis Obturator externus Iliacus

Comparison of the functional anatomy of the deltoid and hip

Similar to the the links of a chain, the hip significantly affects and is affected by the adjoining articular linkages. Most notably, the hip is directly affected by the position of the pelvis. The pelvis is comprised of four bones: the two innominate attached anteriorly at the pubic symphysis and posteriorly to the sacrum and coccyx. The shape of the pelvis varies among individuals as well as between genders. For example, the female pelvis tends to be wider and shallower than the male pelvis which potentially increases flexibility of the lumbo-pelvic-hip complex (Alter).

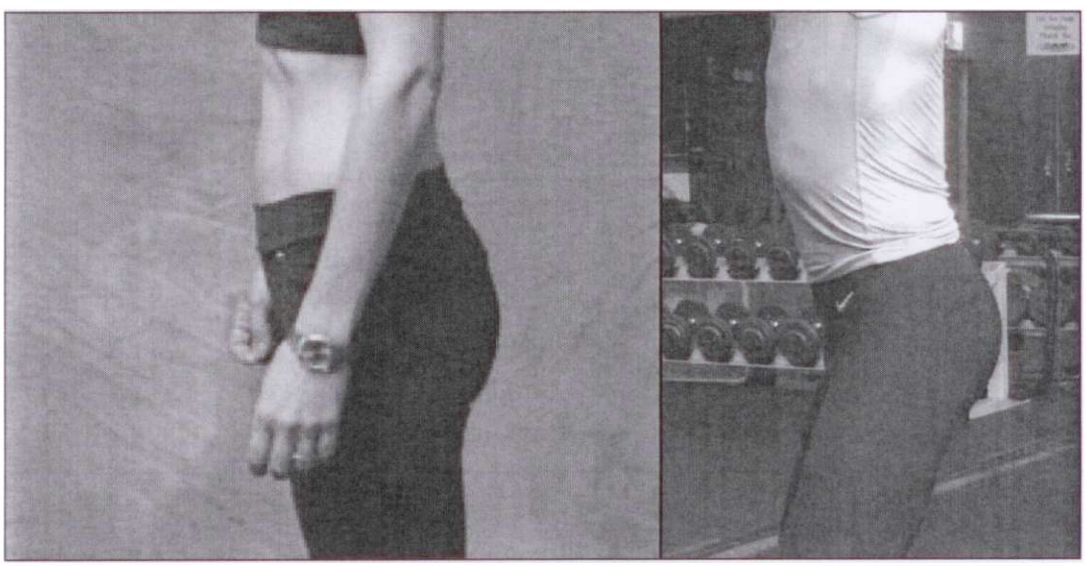
Pelvic alignment directly affects the hip by altering the position of the head of the femur in the acetabular fossa. An anterior rotation or tiliting of the pelvis tends to move the head of the femur towards the back of the fossa whereas a posterior rotation tends to move the head of the femur towards the front of the socket. Therefore, it is imperative to maintain a neutral position of the pelvis in order to maintain proper length tension relationships of the muscles affecting the hip joint.

Neutral Alignment of the Pelvis



The pelvis is in a neutral alignment when the anterior superior iliac spine (ASIS) and public symphysis (PS) are in the same vertical plane. The pelvis is in an anterior tilt (rotation) when the ASIS is anterior to the PS symphysis. The pelvis is in a posterior tilt (rotation) when the ASIS falls posterior to the PS. Optimal length tension relationships of the muscles of the lumbo-pelvic-hip complex occur when the pelvis is in a neutral position. Neutral positioning of the pelvis is important in maintaining proper alignment of the hip joint.

Pelvic positioning. The image on the left below demonstrates neutral positioning of the pelvis. The image on the right demonstrates a slight anterior tilt of the pelvis. This position is a safe beginning posture for many movement patterns as this is the athletic stance for many sports specific drills. Additionally, many experts recommend a slight anterior pelvic tilt when attempting to maximize running speed and agility (Kielbaso).



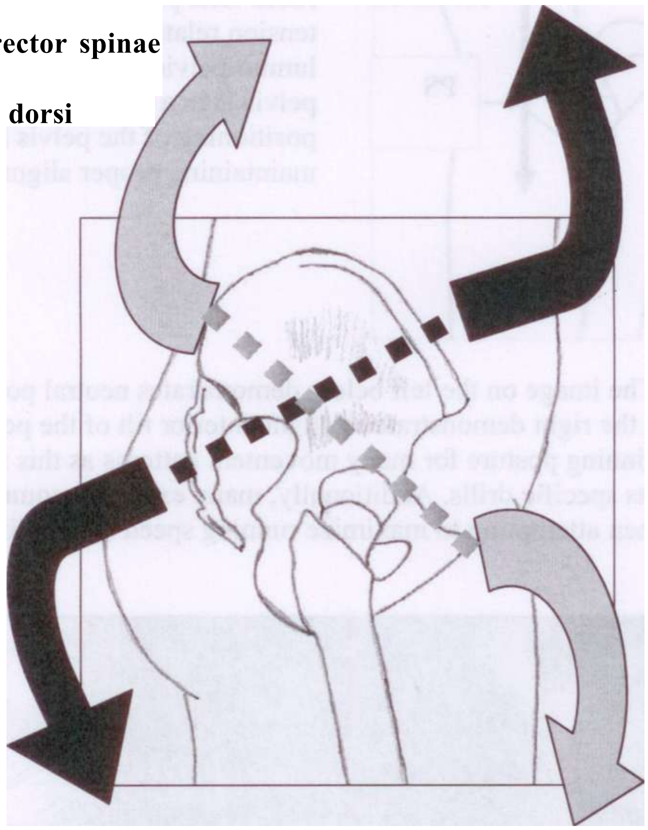
Neutral pelvis (left) and anterior pelvic tilt (right)

Force Couples Affecting the Hip

Several force couples are responsible for maintaining the proper positioning of the pelvis. **Force couples** are muscles that work together, usually pulling in opposite directions, to create rotation of a joint and maintain an optimal instantaneous axis of rotation (see table below). In simpler terms, this refers to the muscles that work synergistically to provide equal and optimal forces around the joint during any movement. Listed below is a schematic representing the force couples affecting the lumbo-pelvic-hip complex.

Lumbar erector spinae
Multifidus
Latissimus dorsi

Abdominals
Psoas major



Hip extensors and
Pelvic floor
-Gluteus maximus
-Hamstrings
-Pelvic floor complex

Hip flexors
-Rectus femoris
-Tensor fascia latae
-Sartorius
-Iliacus

FORCE COUPLES	ACTIONS
Abdominals and gluteus maximus/ hamstrings	Posterior rotation (tilting) of the pelvis
Lumbar extensors and hip flexors	Anterior rotation (tilting) of the pelvis

Force couples of the lumbo-pelvic-hip complex

Alterations in the force couple relationships can have a dramatic impact on one's performance. An example of an altered force couple relationship resulting in a common postural dysfunction seen in many individuals is a posterior rotation of the pelvis secondary to a prolonged seated posture. This posture, common in many individuals who spend hours sitting in front of the computer or television, tends to create a lengthening of the lumbar erector spinae and hip flexors, specifically the psoas. There is a subsequent shortening of the deep hip rotators and abdominals, specifically the external obliques.

Posterior rotation of the pelvis secondary to prolonged sitting is often further patterned by specific exercise cueing such as "pull in the abdominals," "stand up tall" and "squeeze the glutes tight" in addition to exercises that encourage posterior rotation of the pelvis such as cueing the low back to remain flat or in contact with the ground during supine abdominal crunches as well as allowing the back to lose its normal lordosis while squatting. This is also a common postural fault in sports where the aesthetics or form are important, e.g. dancers and gymnasts, since it gives the illusion of creating an aesthetically appealing posture. However, this posture has very significant ramifications on function as Hodges and others have noted optimal activation of the local system of the core (specifically the transversus abdominus) when the pelvis is in a neutral position and increased activation when in a slightly anterior tilted position.

Posterior tilting of the pelvis leads to altered recruitment strategies and decreased ability to control forces through the entire lumbo-pelvic-hip region and therefore decreased function of the kinetic chain. Additionally, a posterior tilted position of the pelvis tends to decrease the force production of the gluteus maximus secondary to the shortened length of the muscle. This tends to decrease the ability to generate extension force during any event that requires maximal hip extension, most notably running and jumping. An even greater detriment to function is the decrease in force reduction, or the ability to control forces during the deceleration phase of a jump. This has routinely been observed to be a leading cause of lumbar disc injuries secondary to the compressive forces resulting from the flexed position of the lumbar spine. Another common injury pattern, especially common to the female athlete, is an increased incidence of knee injuries secondary to decreased ability to properly decelerate the forces generated through the lower extremity during landing. This tends to be a leading cause of injuries to the anterior cruciate and other soft tissue structures of the knee.

As mentioned previously, altered length tension relationships have been linked to increases incidence of lower extremity injuries in female athletes. Postural changes such as genu recarvatum (knee hyperextension secondary to short quadriceps and over-lengthened hamstrings), has been reported to be one of the causative factors in female athletes suffering anterior cruciate injuries. While more common in individuals demonstrating an anterior pelvic tilt, genu recarvatum can be seen in individuals demonstrating a posterior pelvic tilt as well.

The above examples of how an alteration in length tension relationships demonstrate the need for the strength and conditioning specialist to be aware of the dramatic ramifications that postural alterations have on the biomechanics and muscle function of the lumbo-pelvic-hip complex. In conclusion, it is important to teach and to monitor continually for a neutral position of the spine and pelvis in order to maximize performance. Alterations in the pelvic position will alter the length-tension relationship of the force couples responsible for controlling pelvic position, potentially decreasing performance while at the same time increasing the likelihood of injury.

Range of Motion in the Hip

Ranges of motion in the hip and a listing of muscles producing those motions are presented in the chart below. It is important to recognize that these ranges are averages and variations will exist among individuals depending upon several factors including height, weight, muscle mass, gender, limb dominance and chosen athletic activity.

Hip	Movement	Range	Muscles responsible for movement
	Flexion	120-135°	Psoas major
			Iliacus
			Sartorius
			Pectineus
			Adductor longus/ brevis
			Adductor magnus (anterior fibers)
			Tensor fascia latae
			Gluteus medius (anterior fibers)
	Extension	10-30°	Gluteus maximus
			Adductor magnus (posterior fibers)
			Gluteus medius (posterior fibers)
			Semitendinosus/ Semimembranosus
			Biceps femoris (long head)
	Abduction	40-45 °	Sartorius
			Tensor fascia latae
			Gluteus medius/ minimus
			Piriformis (when hip is flexed)
			Gluteus maximus (upper fibers)
	Adduction	20-30 ^{0}	Iliacus
			Psaos major
			Adductor complex
			Gluteus maximus (lower fibers)
	External rotation	40-45 °	Psoas major
			Iliacus
			Sartorius
			Obturator externus/ internus
			Gemellus superior/ inferior
			Biceps femoris (long head)
			Piriformis
			Adductor complex
			Gluteus maximus (upper fibers)
	Internal rotation	40-45 ^{0}	Tensor fascia latae
			Gluteus medius
			Semimembranosus/ semitendinosus
			Adductor magnus (oblique fibers)

HIP MOTION DURING FUNCTIONAL MOVEMENT PATTERNS

During movement patterns that include level changes of the lower extremity, i.e. squats and lunges, equal movement contributions from the hip, knee and ankle complexes are absolutely vital to maintaining appropriate forces around all joint structures involved if one is to avoid the accumulation of potentially damaging forces at any one particular articulation.

For example, a common movement dysfunction noted in the lower extremity is restriction in the posterior hip region. See below for postural causes of posterior hip restriction.

CAUSES OF POSTERIOR HIP RESTRICTION

> **Muscular tension: This is perhaps the most common cause of hip restriction in individuals not experiencing traumatic, degenerative changes of the hip joint. In individuals with weakness of the local stabilization system, especially of the lumbo-pelvic-hip complex, a common substitution pattern is to "grip" or hold from the external rotators of the hip. This causes the head of the femur to be pushed forward in the socket thereby creating an anterior migration of the femoral head. This alters the instantaneous axis of rotation of the hip joint and changes the force couples around the hip socket that perpetuates this positioning during functional movement patterns.**

> **Alterations in the axis of rotation: Any change in the position of the pelvis and/or changes in the length/tension ratio of the hip muscles can change the position of the femur in the socket and alter the axis of rotation. For example, a posterior pelvic tilt, commonly secondary to a "butt grip" pattern of pelvic stabilization, will shift the head of the femur forward in the socket creating a lengthening in the anterior hip capsule and a shortening in the posterior hip capsule.**

> **Altered muscle recruitment patterns: Alterations of the axis of rotation which can either be a cause of or occur secondary to altered recruitment strategies can alter the function of the muscles surrounding a joint. For example, the tensor fascia latae and rectus femoris often become the dominant hip flexors (synergist dominance) when there is weakness in the iliacus, creating an anterior migration of the femoral head during any pattern that requires hip flexion. This can lead to a chronic over-stretching of the anterior hip capsule and a shortening of the posterior hip capsule.**

> **Capsular restriction: The posterior hip capsule often becomes stiff and fibrotic following prolonged postures in which it is maintained in a shortened position (see anterior hip positioning above) due to an altered length/tension ratio. It may also become stiff and fibrotic following trauma to the hip, i.e. a fall on the hip or direct trauma secondary to a sports or motor vehicle accident. The most common cause of capsular restriction tends to be**

repetitive trauma which is common with muscular imbalances of the trunk, pelvis or lower extremities.

> **Degenerative changes: Degenerative changes of the hip (osteoarthritis) are typically seen in middle aged or older clients secondary to either acute injury (macrotrauma) or repetitive injury (microtrauma). In these individuals, there are actual changes in the bony architecture and a remodeling of the femoral head and/or the acetabular fossa. This is often the final outcome in individuals who have long standing changes in the axis of rotation secondary to muscle imbalances and altered recruitment strategies. During a conversation with an orthopedic surgeon who performs hip replacements, he commented that the majority of patients needing hip replacement had no known trauma to the hip suggesting that repetitive injuries are the underlying cause of hip degeneration.**

"Snapping" Hip Syndrome

One of the most common complaints involving the hip is the "snapping", "clicking" or "popping" hip syndrome. It is characterized by an audible or palpable click as the individual attempts to straighten the leg from the supine position. It is most commonly experienced near or at the end range of hip extension.

There have been several proposed theories as to the origin of this clicking including the tendon of the psoas flipping over the lesser trochanter or hip bursa, crepitus from an unstable lumbar vertebrae or sacroiliac joint or instability at the pubic symphysis. While the mechanisms of this clicking or popping may vary among individuals, clinically the most common cause is weakness of the local system, particularly within the deep fibers of the psoas. The deep fibers of psoas are part of the local system of the lumbo-pelvic-hip complex and function to maintain lumbar spine stability during hip mobility. Typically the clicking or popping occurs toward the end range of hip extension (with the individual in a supine position) where there is the longest lever arm subsequently placing a large demand on the entire local system of the lumbo-pelvic core and greatest eccentric load on the psoas muscle. Weakness of any component of the local system of the lumbo-pelvic core will result in a "clicking" or "popping" sensation which can be palpated by placing the hand posteriorly adjacent to the lumber spine or sacroiliac joint or anteriorly, just inside the ASIS. The actual clicking usually occurs as the psoas tendon flips over the lesser trochanter of the femur, superior ramus of the ilium or from an instability at one of the vertebral attachments of the psoas. It is seen clinically in virtually every client that has had some type of lumbar surgery (disectomies, laminectomies and fusions) due to the inhibition and resultant weakness of the local system and subsequent hypermobility of the lumbar spine surrounding the segment.

The clicking or popping may also occur secondary to pelvic obliquity (alteration in the alignment of the ilia left compared to right), lumbar spine rotation or a change in the axis of rotation of the hip joint. While any misalignment in the spine or pelvis need to be addressed by a chiropractic physician or physical therapist, restoring an ideal axis of rotation can be achieved through specific relaxation techniques that are utilized to re-seat or reposition the location of the femoral head in the acetabular fossa. Most commonly, we have found the femoral head migrates anteriorly secondary to restriction in the posterior hip region (see causes of this in earlier section) and/or over-activation of the tensor fascia latae usually in response to a weak psoas. Reseating the femoral head must then precede any strengthening of the psoas or local system because of the altered length tension ratios that occurs as a result. *See later section for specific techniques for reseating the femoral head and restoring proper function of the psoas and local system.*

Other techniques that have been shown to be useful in addressing a snapping hip include chiropractic manipulation to the sacroiliac joint or lumbar spine, myofascial release over the psoas muscle and specific contract/relax techniques to the surrounding hip musculature. An abstract in the January 2005 issue of the *Journal of Manipulative and Physiological Therapeutics* reported specific techniques addressing internal snapping hip syndrome in a 32 year old marathon runner. The author's approach included specific

manipulations to the lumbo-pelvic region and soft tissue techniques to the psoas which resolved the symptoms after 2 weeks of care.

Hamstring injuries

Hamstring injuries are a common affliction affecting athletes involved in running, sprinting, and jumping. Several risk factors have been identified by individuals in the conditioning and rehabilitation industries including tight hamstrings, weak hamstrings, age, fatigue, and inappropriate warm-ups. While most theories seem to be based largely upon personal experience, a literature review of the research on this issue does little to add any clarity. There seem to be few if any, evidence-based approaches to the prevention and treatment of hamstring strains. This section will discuss several myths, review some of the current literature and present a paradigm for the prevention and conditioning of hamstring injuries. This approach has been extrapolated from the current research on lumbo-pelvic-hip stabilization in addition to clinical experience and discussions with several strength and conditioning experts.

The "pulled" or, more accurately, strained hamstring muscle is a common ailment of found in almost any sport or activity that requires explosive speed, rapid deceleration or jumping. Some studies show that the biceps femoris seems to be the most commonly injured of the hamstring muscles and that the injury itself tends to occur during the eccentric phase of terminal swing phase of gait. Other studies have demonstrated injuries to the semitendinosus and semimembranosus. Many times, once an individual experiences a hamstring strain, there is a tendency to experience chronic problems or multiple strains of the same hamstring muscle. It is common for athletes to experience a "pulled" hamstring that plagues them the entire season. Last year, a high profile professional NFL football player pulled a hamstring on the very first play from scrimmage during the summer practice sessions. The injury kept him out of several games this past year and limited his effectiveness in the games he did participate in. Why are hamstring injuries so rampant in sports, even in highly conditioned athletes that are being trained by the best strength and conditioning coaches in the industry?

Varying ideas have been proposed concerning the origin of hamstring strains. Some of these are based upon biomechanics while others are based more on clinical experience and still others are based purely on myths rather than evidence based validation. Several of these theories will be presented below along with alternate view points that are based upon the research, discussions with other health professionals and anecdotal evidence.

1. **The individual has "tight" hamstrings.** If you were to ask an athlete why they thought they had pulled a hamstring muscle, what do you think their likely answer would be? If you polled 100 athletes, the large majority would answer tight hamstrings. Perhaps the most commonly held belief is that hamstring strains are the result of "tight" hamstrings, specifically, short and tight hamstring muscles. Unfortunately, this theory has been around for several decades and never seems to go out of style. In fact, it seems that it is perpetuated by each new generation of

athletes and conditioning coaches alike. In Complete Core Conditioning I related a story about the consultation I had with a professional baseball player whose conditioning coach and chiropractor repeatedly told him he had to stretch his "tight" hamstrings. When asked how many time he had pulled his hamstring in his career (he had been playing baseball since he was in grade school) he replied never. My advice to him was to continue to develop dynamic flexibility and forget about trying to lengthen his hamstrings. Recall the NFL athlete above who suffered the hamstring pull during the first play from scrimmage in summer training camp? A picture that appeared in the local newspaper, taken just prior to the beginning of practice showed the athlete on the ground performing a static, hurdlers stretch for his hamstring muscle. Minutes later he suffered a significant hamstring strain. Is it merely coincidence or have we merely been lead astray by many of the "experts" in the field who think that increased length of muscles in a static position (i.e. static flexibility) relates to improved performance on the field. There is not one research article to my knowledge that has successfully attributed short hamstring muscles to an increased incidence of hamstring pulls. In fact, Stuart McGill, who consults with many world class and Olympic athletes suggests that most of the top sprinters and power athletes have the "tightest" hamstrings. It is the tightness in the muscles that allows the athlete to store incredible elastic energy and enable them the explosive power to create top speed and strength. So is there any benefit to stretching the hamstring muscles and what advice should be given to an individual that does have short and stiff hamstrings? While hamstring stretching has been shown to have a benefit in the rehabilitation of a hamstring strain and as part of an integrated strength and conditioning program, few if any studies have demonstrated that increases in hamstring length in and of itself will prevent hamstring injury.

2. **The individual has "weak" hamstrings.** Many of the same proponents of the tight hamstring camp also subscribe to the theory that hamstring injuries occur because the hamstrings are too weak. However, this is rarely based upon any functional testing and standardization of hamstring strength is difficult to determine. If weak hamstrings are identified as a cause of hamstring injuries, which exercises do many individuals usually recommend- leg curls performed in a lying (prone) position. While one function of the hamstring is to curl the knee, this is not the main function which is only one of several inherent problems with this exercise. The following section will identify the functional role of the hamstring muscles and why the hamstring curl machine may potentially set an individual up to experience a hamstring injury.

   First, as mentioned, the primary goal of the hamstring muscle is not to curl the knee as is taught in most anatomy classes. The functional role of the hamstring muscles are summarized below.

FUNCTIONAL ROLE OF THE HAMSTRING MUSCLES

- Deceleration of hip flexion and knee extension at the end of the swing phase of gait- at terminal swing the hamstring functions eccentrically to decelerate flexion of the hip flexion and extension of the knee.

- Deceleration of knee flexion during any activity that requires closed chain action of the knee- during the loading phase of gait, as well as during the descent phase of a squat or lunge, the hamstring muscles work eccentrically as "check reins" (similar to that used to control a horse's head) to control pronation (flexion and internal rotation of the knee). Essentially, they function to decelerate anterior migration and internal rotation of the tibia.

- Accelerate hip extension and knee flexion during forward propulsion- the hamstrings function concentrically to extend the hip and flex the knee during the gait sequence. It is important to note that knee flexion occurs in an open chain position with the only load being the weight of the lower leg. Additionally, the hamstrings can aid the quadriceps in knee extension by decelerating anterior migration of the tibia as the body moves over the tibia and ankle.

- **Stabilization of the sacrum and pelvis- the long head of the biceps femoris originates from the ischial tuberosity of the pelvis and has fascial**

  the more lateral attachments of the semitendinosus and semimembranosus to attach to the lateral aspect of the tibial tuberosity and head of the fibula. As part of the deep longitudinal chain, it functions to stabilize the sacrum at heel contact during any functional movement pattern.

As pointed out above, knee flexion is only a limited function of the hamstring muscles. Therefore, dysfunction may be created by performing weighted leg curls as the primary exercise for the hamstring. Several reasons for this are proposed below.

A. Hamstring curls are performed in a lying, seated or stabilized standing position with the hamstrings functioning in a fairly isolated manner. Virtually all athletic activities and activities of daily living require the body to be in an upright position while accelerating, stabilizing and decelerating the body through 3 planes of motion. This enables the proper proprioceptive input to be received from all aspects of the kinetic chain and facilitates proper synergy between all the muscle groups surrounding the pelvis, hips, knees and ankles which is not possible while performing a leg curl on a standing, seated or standing leg curl machine.
B. Research has demonstrated most injuries of the muscular system occur secondary to poor eccentric control. Incidentally, this happens to be the most common cause of strains of the hamstring muscles as well. Most hamstring injuries occur either

at the end of the swing phase (maximal flexion of the hip and extension of the knee) or at heel contact during the transition between eccentric lengthening and concentric shortening of the muscle. An over-reliance on leg curl machines creates great concentric strength but does very little for improving the eccentric strengthening of the hamstring muscle.

C. During all hamstring exercises performed on a machine, the hamstrings are loaded from the ground up. In other words, the load (external weight) on the hamstrings is below the axis of rotation (at the knee). In an upright or functional position, the load (bodyweight) is always above the axis of rotation. While unsubstantiated by any literature I have come across, clinically I have found that this alters the recruitment pattern and normal strength curve of the hamstring muscles.

D. The lying hamstring curl is actually a very beneficial exercise for teaching neutral spine while creating a lengthening of the rectus femoris. However, most individual perform this exercise with far too much weight and end up creating an anterior shearing of the lumbar vertebrae (observed as an increase in the lumbar lordosis- see image below).

3. **Alterations in pelvic alignment.** Alterations in pelvic alignment are rarely considered as causes of hamstring pulls. However, pelvic obliquity (rotation of one ilia in relation to the other) will cause a change in the length/ tension ratio of the hamstring muscles. Recall that any change in the length of a muscle results in a change in the length of the muscle fibers and therefore a decrease in the efficiency of muscular contraction. For example, if there is an anterior rotation of the right ilia, there will be an increase in the length of the hamstrings on the right increasing the resting tone of the muscle prior to activity. This will result not only in a decrease in the force production (concentric action) of the muscle but more importantly, there will a significant overstretching that occurs and decreased efficiency at the end of the swing phase of gait where the hamstring muscle is required to decelerate flexion of the hip and extension of the knee (at the point where many hamstring pulls occur). Similarly, if the ilia is in a posterior rotation, the hamstring muscle is placed in a shortened position. Like the above scenario, the resting tone of the hamstring is often increased and when it is called upon to rapidly decelerate flexion of the hip and extension of the knee, the muscle may spasm because it will not lengthen or potentially create a micro-tear within the muscle belly. Additionally, pelvic obliquity will create a torsion that often leads to dysfunction and inhibition within the local system of the core which often leads to an increase in the resting tone of the of the hip rotators and hamstring muscles due to its connection to the sacrum with a similar result as noted above. Therefore pelvic alignment should be established prior to any treatment of the hamstring.

4. **Decreased gluteus maximus control.** Comerford and others have demonstrated impaired gluteal function, especially of the lower, medial fibers. These fibers tend to have a line of pull that directs the hip posteriorly in the socket and maintains an optimal axis of rotation. Trauma, overuse and improper exercise are three common causes of gluteal inhibition. With gluteal inhibition, the hamstrings assume a postural role resulting in an increase in their resting tone. When they are

then called upon for dynamic action, there is a tendency for injury as the neuromuscular system first response will be to control posture before it will give in to movement.

This section has outlined several clinical observations and theories regarding the causes of hamstring strains while providing theoretical evidence as to why we choose to avoid some of the commonly held beliefs in training and rehabilitation of hamstring injuries. The specific exercises we use to train and condition the hamstrings will be outlined in the following section.

Prevention and Training Strategies

Several factors have been identified in reducing the risk of injury. Recent evaluations of Australian football players demonstrated that younger athletes and those with increased quadriceps flexibility were at a decreased risk of sustaining a hamstrings injury. Increasing anaerobic interval training, stretching the hamstrings at the point of fatigue and adding sport specific training appeared to significantly reduce the rate and incidence of hamstring injuries.

Recently, attention has turned to core stabilization and muscle imbalances as risk factors for lower extremity injuries in athletes. While the research seems to be inconclusive at this time, there appears to be a relation between improving function of the core and improved lower extremity performance. Work by Sahrmann, Hodges, Lee and Lee demonstrate improved lower extremity performance with proper activation of the lumbo-pelvic-hip stabilizers particularly the transversus abdominus, multifidus, deep fibers of gluteus maximus, deep fibers of psoas, and muscles of the pelvic floor. The following section will outline a specific training protocol for functional hamstring conditioning.

References as presented at PubMed- www.ncbi.nlm.nih.gov

Askling C, Tengvar M, Sarrtok T, Thorstensson A. Sports related hamstring strains-two cases with different etiologies and injury sites. Scand J Med Sci Sports. 2000 Oct;10(5):304-7.

Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. Am J Sports Me. 2004 Jan-Feb;32(1 Suppl):5S-16S.

Dadebo B, White J, George KP. A survey of flexibility training protocols and hamstring strains in professional football clubs in England. Br. J Sports Med. 2004 Aug;38(4):388-94

Gabbe BJ, Finch CF, Bennell KL, Wajsweiner H. Risk factors for hamstring injuries in community level Australian football. Br J Sports Med. 2005 Feb;39(2):106-10.
Kujala UM, Orava S, Jarvinen M. Hamstring injuries. Current trends in treatment and prevention. Sports Med. 1997 Jun;23(6):397-404.

Hoskins W, Pollard H. the Management of hamstring injury- Part 1: Issues in diagnosis. Man Ther. 2005 May; 10(2):96-107.

Hoskins W, Pollard H. the Management of hamstring injury- Part 2: Issues in diagnosis. Man Ther. 2005 Aug; 10(3): 180-90.

Kujala UM, Orava S, Jarvinen M. Hamstring injuries. Current trends in treatment and prevention. Sports Med. 197 Jun;23(6):397-404.

Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc. 2004 Jun;36(6):926-34.

Malliaropoulos N, Papalexandris S, Papalada A, Papacostas E. The role of stretching in rehabilitation of hamstring injuries: 80 athletes follow-up. Med Sci Sports Exerc. 2004 May;36(5):756-9.

Nadler SF, Malanga GA, Bartoli LA, Feinberg JH, Prybicien M, Deprince M. Hip muscle imbalance and low back pain in athletes: influence or core strengthening. Med Sci Sports Exerc. 2002 Jan;34(l):9-16.

Nadler SF, Malanga GA, Feinberg JH, Rubanni M, Moley P, Foye P. Functional performance deficits in athletes with previous lower extremity injury. Clin J Sports Med. 2002 Mar;12(2):73-8.

Petersen J, Holmich P. Evidence based prevention of hamstring injuries in sports. Br. J Sports Med. 2005 Jun;39(6):319-23.

Sherry MA, Best TM. A Comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. J Orthop Sports Phys Ther. 2004 Mar;34(3):l 16-25.

Verall GM, Slavotinek JP, Barnes PG. The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. Br. J Sports Med. 2005 Jun;39(6):363-8.

Verrall GM, Slavotinek JP, Barnes PG, Fon GT. Diagnostic and prognostic value of clinical findings in 83 athletes with posterior thigh injury: comparison of clinical findings with magnetic resonance imaging documentation of hamstring muscle strains. AM J Sports Med. 2003 Mov-Dec;31(6):969-73.

Anterior Cruciate Ligament Injuries

Injuries involving the anterior cruciate ligament (ACL) in addition to the medial collateral ligament (MCL) and medial meniscus (MM) are rampant in both the athletic and non-athletic population. Women seem to be at a greater risk as evidenced by the higher incidence of these types of injuries that occur in the female population regardless of sport or occupation. As with many musculoskeletal conditions, there are a number of perpetuating myths surrounding the origins of these injuries as well. To simplify the discussion, injuries to the ACL, MCL and MM will be grouped together since they often have a similar mechanism and often are injured in unison.

Role of the Anterior Cruciate Ligament

The ACL consists of two bands that run from the posterior aspect of the femoral condyle to attach to the medial tibial eminence. It functions as the primary restraint to anterior shear of the tibia and secondarily to internal rotation and valgus forces on the knee (Moeller and Lamb). It acts with the posterior cruciate ligament as an axes of rotation for knee movement (Moeller and Lamb).

Females experience almost twice the number of ACL injuries as compared to males. Females participating in soccer, volleyball and basketball tend to have a higher incidence of ACL injuries as compared to other sports. Interestingly, most injuries involving the ACL are non-contact injuries meaning that there is no direct trauma that results in the injury. The mechanism of injury to the ACL tends to be flexion, adduction and internal rotation of the knee and typically occurs with rapid changes of direction. Essentially these injuries occur as the athlete attempts to decelerate her momentum and quickly change direction. If that is the case, then what are the underlying causative factors behind these injuries? There are several purported theories behind the increased incidence of injuries in females and several of these will be discussed below.

Women have a greater "Q" angle. The most common reason given as to why women have an increased incidence of knee injuries is that they have a greater Q angle than men. The Q angle, also known as the quadriceps angle, is the angle that is formed between a straight line drawn from the ASIS to the mid-patella and from the mid-patella to the tibial tubercle. The angle in women averages around 18° where as in men it tends to average around 13°. An increase in the Q angle typically tends to occur with an increase in genu valgus (knock knee) potentially leading to several conditions involving the knee including: alterations in the positioning of the patella (usually superior and lateral) leading to patellar tracking problems and chondromalacia patella, and external rotation of the tibia which increases the torsion on the ACL, MCL and MM. The reasons for the increased angle in women include:

- A wider pelvis which positions the ASIS more laterally
- A decrease in the angle of the femoral neck
- Slightly greater degree of ligament laxity of the medial collateral and anterior cruciate ligaments of the knee and spring ligament of the foot

2. **Biomechanical alterations.** Factors such as alignment issues of the lower extremity including hip anteversion, external tibial rotation and forefoot pronation seem to be related to greater incidences of knee injuries in females.

3. **Hormonal factors.** Increase in hormones, especially around the premenstrual and menstrual phases of the cycle tend to increase susceptibly of female soccer players to injuries (Biondino). However, taking oral contraceptive seemed to decrease the incidence of injuries in female soccer athletes.

So what does the literature have to contribute to the cause and prevention of ACL injuries? Research has demonstrated deficits in feed-forward (anticipatory) motor control in individuals experiencing low back pain leading to altered stabilization patterns of the lumbo-pelvic-hip region. A recent study looked at changes in ground reaction forces during jump landing in individuals that demonstrated ankle instability. Interestingly, multi-directional instabilities were detected in individuals that experienced previous ankle injuries leading the authors to conclude deficits in motor control were present. This information is incredibly valuable to the strength and conditioning specialist as it points to the importance of evaluating previous lower extremity injuries and the potential dysfunction that occurs as a secondary to altered neuromotor control and resultant compensatory movement patterns.

Studies have shown that females tend to demonstrate greater internal rotation forces and higher knee stiffness values than males during single leg land (from single leg jumping). Research has shown that females possessing higher levels of joint laxity in the knee demonstrated increased activation of the gastrocnemius and biceps femoris in response to lower extremity perturbations which may explain some of the increased stiffness values as noted in the previous study. Much of the literature suggests variations between male and female biomechanics in landing from jumping. While some researchers have demonstrated that female athletes landed with accelerated and greater degrees of knee flexion, others have demonstrated that female athletes exhibit significantly lower knee and hip flexion angles and higher ground reaction forces as compared to male athletes. Similar studies have shown differences in muscle activation patterns including decreased gluteal activity and increased quadriceps activity in female collegiate athletes as compared to their male counterparts. The quadriceps act as an antagonist to the ACL, creating an anterior shear force on the tibia whereas the hamstrings and soleus act as agonists to the ACL by providing posterior checks to anterior movement of the tibia.

Prevention of ACL Injuries

There tends to be a new sports specific and injury prevention program popping up in every gym and rehabilitation clinic. However, many of these programs continue to focus on force production (usually with the use of machines) and an over-reliance on plyometrics, mainly jumping. In fact, recently the local news ran a special on a local rehabilitation clinic that was running a highly acclaimed knee injury prevention program. There were several female high school athletes performing jumping drills. Each time these athletes landed, an increased knee flexion with minimal hip flexion was observed.

Recall, this is one of the proposed mechanisms of ACL injuries. In discussions with parents who have placed their adolescent female athletes in one of these acclaimed programs, they report that these coaches have the athletes jump continuously for hours at a time with little emphasis on teaching proper technique. It was interesting to note that there was an increase in knee injuries that year on that team and almost half the girls on the team quit. While these are not isolated cases, there seems to be an erroneous approach to training both athletes and the general population. It is common to witness personal trainers utilizing similar programs for their general clientele that are used with high level athletes. More often than not, there is little to no emphasis placed upon technique. Unfortunately, the industry is inundated with a monkey see, monkey do mentality with little regard to why a particular exercise or program is being utilized. In fact, there seems to a contest with many trainers as to who can make their client do the highest level exercise.

While an entire chapter could be devoted to the ill-advised programs of many of the industry's strength and conditioning specialists, it seems more appropriate to discuss just what constitutes proper mechanics and what components comprise a proper injury prevention and conditioning program.

Prevention Strategies

There are many varying strategies and schools of philosophy in the rehabilitation, treatment and exercise strategies for hamstring and knee injuries. Listed below are some of the concepts that I employ and have yet to have an individual that follows this program religiously experience a non-contact injury to the hamstring and/or knee. This is not to say this program will guarantee that your athletes or clients will not ever experience an injury if they follow this program. As the saying goes, "Life happens." However, if this program is adhered to and progressed in a sensible manner, your athletes and clients will undoubtedly discover a renewed feeling of efficient movement, improved performance and decreased incidences of injuries.

While the philosophy is very simple, however, each component must be employed to guarantee success. The three components are listed below.

- Ensure proper activation and motor control of the core while addressing proper verbal instructions for both the core and lower extremity mechanics. Research has demonstrated that instructing the individual in the proper control of neutral spine prior to adding complex movement patterns involving limb motion or external resistance aids in the motor control of the lumbo-pelvic-hip complex.

- Teach and constantly monitor to ensure proper execution of the fundamental movement patterns:
    - Changes in center of gravity- there should be a large amount of time dedicated to teaching the proper mechanics of squatting and multi-planar lunging

   - Ambulation- there should be an emphasis placed upon the proper deceleration mechanics especially with hopping, jumping, leaping and bounding
   - Manipulation of extremities- pushing and pulling with alterations in lower extremity positions. Research has demonstrated altered lower extremity mechanics, possibly leading to injuries, in individuals that land while simultaneously catching a ball.
   - Changes in direction- rotating, turning and lateral movements with an emphasis on proper lower extremity mechanics

- Follow the proper progressions:

Uniplanar motion —» Multiplanar motion
Lunges in place —• Lunges in three planes of motion

Isolated joint motion —• Integrated joint motion
Dumbbell bicep curls —• Squat-curl-press combinations

Limited range of motion —• Dynamic range of motion
Tight rotations —• Wide rotations
Chops to waist —> Chops to knee —> Chops to ankle

Slow speeds of motion —> Higher speeds of motion
Squats performed at a 1 rep/4 second rate —• Squats performed at a 1 rep/1 sec rate

Stable surfaces —» Labile surfaces
Squats performed on the ground —* Single leg squats performed on the BOSU

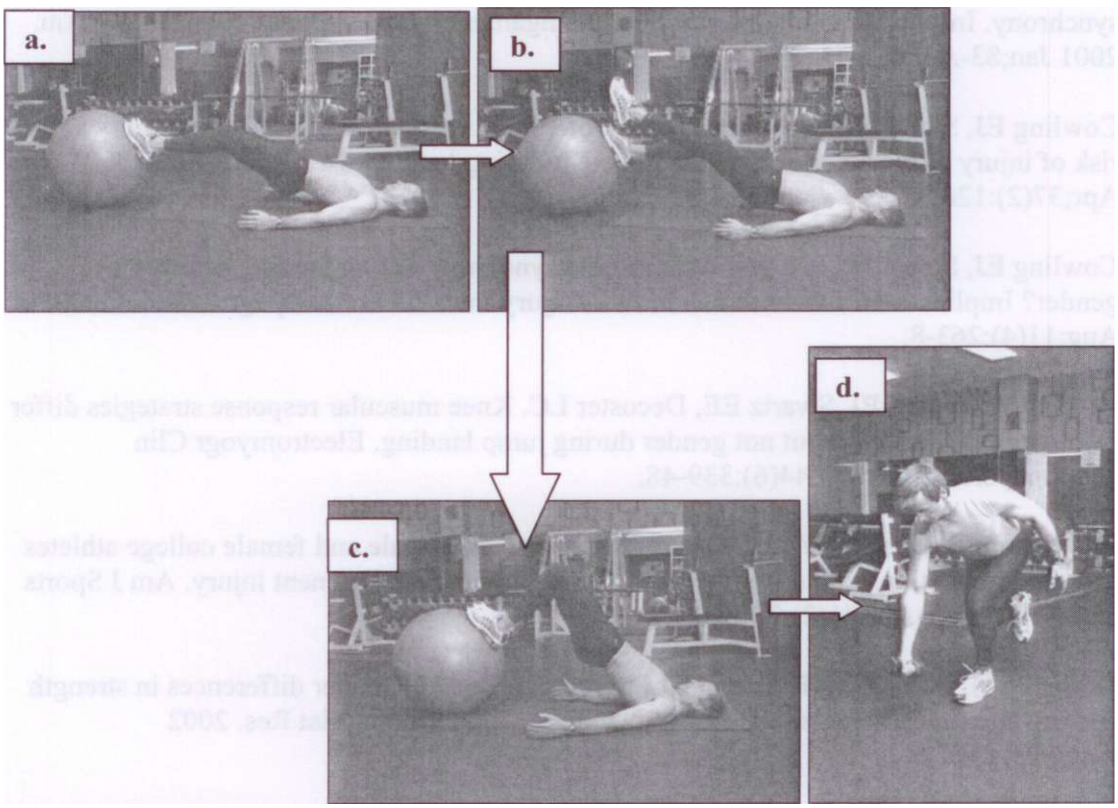
Proper verbal instructions has been shown to improve activation of the local system of the lumbo-pelvic-hip complex. Likewise, verbal instructions to increase knee flexion during landing has demonstrated improvements in the landing mechanics of female athletes potentially decreasing the susceptibility to ACL injuries. Further instructions such as "sitting back in the hips" may additionally have a positive effect in activating the posterior chain (gluteals and hamstring complex) and decreasing the quadriceps activity and subsequent anterior shear forces on the knee.

Keep it simple and let the results speak for themselves. Listed below is one example of these principles. The following routine is extremely effective for functional hamstring conditioning.

Juan Carlos Santana developed the "triple threat" for his athletes and reports none of them has experienced a hamstring pull since beginning that routine. The triple threat is a tri-set consisting of toe bridges on the stability ball followed by heel bridges on the ball

followed by the bridge to knee curl. Each exercise is performed for 15 repetitions in rapid succession and this triple complex is repeated for 2-4 cycles.

I have adapted and modified JC's approach because I felt the need for a weight bearing component in which to train the hamstrings and many of my clients felt that they were loosing flexibility in their hamstrings. The quadruple extension set emphasizes posterior chain mechanics and begins with toe bridges (to teach triple extension), followed by single leg lift offs (to teach pelvic stability with unilateral hip extension), followed by bilateral knee curls (to improve knee flexion strength with pelvic stability) and finishing with single leg anterior reaches (to train eccentric loading and deceleration mechanics of the entire posterior chain). Each set is performed for 10-15 repetitions in succession. Repeat the cycle 2-4 times. This program is equally effective at conditioning the core and lower extremity for the prevention of knee injuries. These exercises are only an example and may be modified depending on the level of conditioning and goals of your client.



Functional compound set: Bilateral ball bridges (a), single leg ball lift-offs (b), stability ball knee curls (c), single leg reaches with dumbbell (d).

See additional exercises and verbal cues in the exercise section.

References:

Biondino, CR. Anterior Cruciate Ligament Injuries in Female Athletes. http://www.arthroscopy.com.

Watson A, Haddad F. ACL- female anterior cruciate ligament injuries review. http://www.sportsinjurybulletin .com

References as presented at PubMed- www.ncbi.nlm.nih.gov

Caulfield B, Garrett M. Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. Clin Biomech (Bristol Avon). 2004 Jul; 19(6):617-21.

Cowling EJ, Steele JR. The effect of upper-limb motion on lower-limb muscle synchrony. Implications for anterior cruciate ligament injury. J Bone Joint Surgery Am. 2001 Jan;83-A(l):35-41.

Cowling EJ, Steele JR, McNair PJ. Effect of verbal instructions on muscle activity and risk of injury to the anterior cruciate ligament during landing. Br J Sports Med. 2003 Apr;37(2): 126-30.

Cowling EJ, Steele JR. Is lower limb muscle synchrony during landing affected by gender? Implications for variations in ACL injury rates. J Electromyogr Kinesiol. 2001 Aug;l l(4):263-8.

Croce RV, Russell PJ, Swartz EE, Decoster LC. Knee muscular response strategies differ by developmental level but not gender during jump landing. Electromyogr Clin Neurophysiol. 2004 Sep;44(6):339-48.

Fagenbaum R, Darling WG. Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury. Am J Sports Med. 2003 Mar-Apr;31(2):233-40.

Lephart SM, Ferris CM, Riemann BL, Myers JB, Fu FH. Gender differences in strength and lower extremity kinematics during landing. Clin Orthop Relat Res. 2002 Aug;(401): 162-9.

Moeller J, Lamb MM. Anterior Cruciate Ligament Injuries in Female Athletes: Why Are Women More Susceptible? The Physician and Sports Medicine - Vol. 25, No. 4, April 1997.

Salci Y, Kentel BB, Heycan C, Akin S, Korkusuz F. Comparison of landing maneuvers between male and female college volleyball players. Clin Biomech (Bristol, Avon). 2004 Jul;19(6):622-8.

Shultz SJ, Carcia CR, Perrin DH. Knee joint laxity affects muscle activation patterns in the healthy knee. J Electromyogr Kinesiol. 2004 Aug;14(4):475-83.

Swartz EE, Decoster LC, Russell PJ, Croce RV. Effects of Developmental Stage and Sex on Lower Extremity Kinematics and Vertical Ground Reaction Forces During Landing. J Athl Train. 2005 Mar;40(l):9-14.

Zanulak BT, Ponce PL, Straub SJ, Medvecky MJ, Avedisian L, Hewett TE. Gender comparison of hip muscle activity during single-leg landing. J Orthop Sports Phys Ther. 2005 May;35(5):292-9.

Section I

The following section will introduce the reader to the basics of anatomy and bio-mechanical concepts that are necessary to fully understand both hip dysfunction and the specific parameters that are necessary to rehabilitate and condition the hip and lower leg.

Planes of Motion

Motion at any given joint in the body occurs within the three primary or cardinal planes of motion.

PLANES OF MOTION

- **Sagittal**
- **Coronal (Frontal)**
- **Transverse**

The **sagittal** plane bisects the body from front to back into right and left symmetrical halves. Flexion and extension motions will occur in this plane. Examples of sagittal plane motion include flexion and extension of the spine, knee and elbow from anatomical position.

The **coronal (frontal)** plane bisects the body from side to side dividing it into front and back halves. Lateral flexion, abduction and adduction motions occur in this plane. Examples include spinal lateral flexion, and abduction and adduction of the shoulder and hip.

The **transverse** plane divides the body into superior and inferior halves. Rotational movements will occur in this plane. Examples include spinal rotation in addition to internal and external rotation of the hip and shoulder.

Motions performed in the sagittal and frontal planes occur either with or against gravity. Extending your hips during the ascent phase of a squat requires a concentric contraction of the gluteus maximus in order to overcome the downward pull of gravity on the bodyweight. Lowering the body or extremity under control requires an eccentric contraction of the muscles due to the downward pull of gravity. For example, bending over from the waist to pick up a magazine from the floor requires an eccentric contraction of the lumbar extensors.

Movements occurring in the transverse plane are perpendicular to the pull of gravity. Therefore, motion in this plane requires muscle activity to both produce and control the motion that is occurring. This would begin to explain why the majority of our muscles are not oriented in a pure vertical or horizontal direction but rather have an oblique fiber direction. For more discussion on this topic, see the section titled Muscle Orientation.

Research has demonstrated most injuries occur in the transverse plane of motion.

It is important to realize the three planes are, in reality, just a point of reference in order to describe motion. Very few motions of the body occur purely in any one plane. It is more common for the body to move through multiple planes during any given motion, which is referred to as **multiplanar** or **triplanar** motion. In fact, most joints we will look at move in all three planes of motion and the muscles that function on the joint act to decelerate, stabilize and accelerate the joint through the three planes of motion. This is the rationale behind designing multi-planar training programs. If most functional activity occurs in three planes of motion, we must train the body in three planes of motion.

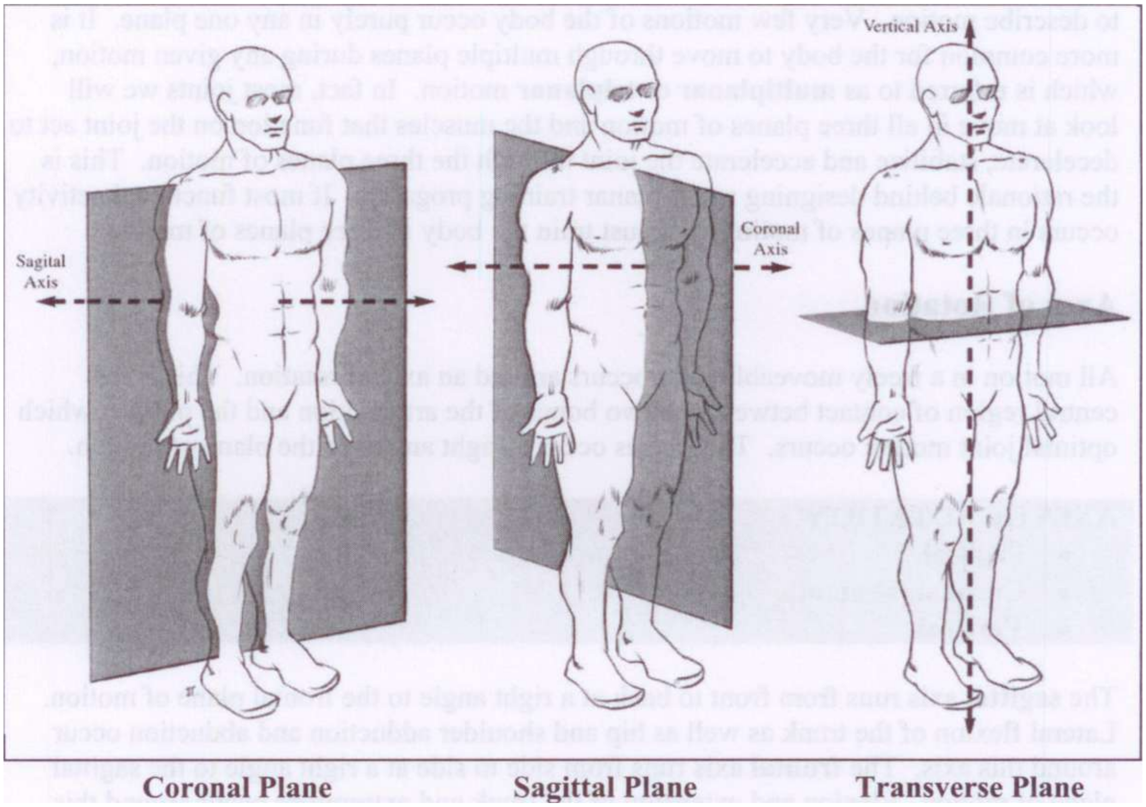
Axes of Rotation

All motion in a freely moveable joint occurs around an axis of rotation. This is the central region of contact between the two bones of the articulation and the point at which optimal joint motion occurs. These axes occur at right angles to the plane of motion.

AXES OF ROTATION

- **Sagittal**
- **Coronal (Frontal)**
- **Vertical**

The **sagittal** axis runs from front to back at a right angle to the frontal plane of motion. Lateral flexion of the trunk as well as hip and shoulder adduction and abduction occur around this axis. The **frontal** axis runs from side to side at a right angle to the sagittal plane of motion. Flexion and extension of the trunk and extremities occur around this axis. The **vertical** axis runs straight downward, in a cephalic to caudal direction. It is at a right angle to the transverse plane of motion. Rotation of the trunk and extremities occurs around this axis.



Planes of Motion and Axis of Rotation

Movement of the spine and extremities occurs around one of three planes of motion. See table below for a list of the plane, axis and motion.

Plane of motion	Axis of rotation	Motions
Sagittal	Coronal	Spine: flexion and extension Extremities: flexion and extension
Coronal	Sagittal	Spine: lateral bending Extremities: abduction and adduction
Transverse	Vertical	Spine: rotation Extremities: external and internal rotation

Planes, Axis and Motions

It is important to note that functional movements (i.e. activities of daily living and sports) do not occur in one plane of motion but are rather a combination of two or more planes. This is referred to as multiplanar or triplanar motion. This is why it is important to train the body using multiple planes, through various ranges of motion and integrating the entire kinetic chain (spine and extremities) into your exercise, rehabilitation and movement program.

Basic Movement Patterns

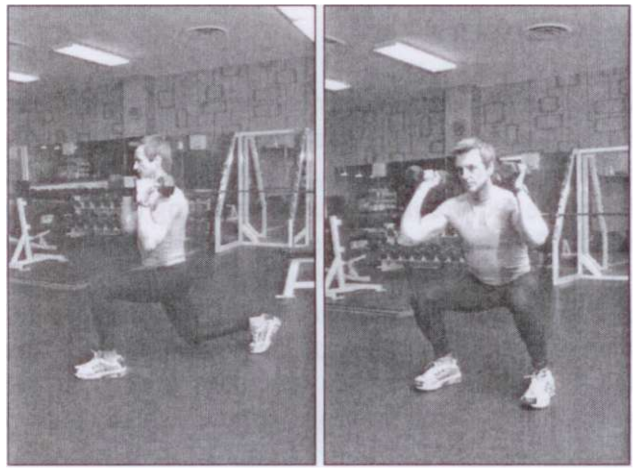
The basis of studying functional anatomy is that by knowing the anatomy of the system, we are then able to better visualize and conceptualize the movement patterns that make up the components of functional training. Designing an effective functional training program necessitates the requirement of understanding the basic movement patterns that need to be improved. The basic function of the body is to create motion in an organized manner in order to perpetuate life. It is important to remember for thousands of years we did not have access to paved roads and sidewalks, fancy footwear, grocery stores and houses and often were the prey of many of the other species of animals. Our neuromusculoskeletal system was highly developed to allow us to forage and harvest plants, hunt for meat, build shelter and to survive the other carnivores.

There are several basic motor patterns inherent to humans that allowed us to survive as primitive man. While thankfully we don't have to worry about being eaten by other animals, these days our movement patterns now allow us to "survive" our current culture of bending and lifting a bag of groceries, stepping into the bathtub, running after the bus, lifting children into car seats, pushing strollers, throwing a ball, hopping over cracks in the sidewalk and swinging a golf club during a weekend golf outing. Juan Carlos Santana refers to these motions as the "Four Pillars of Human Movement," Paul Chek labels these motions as the "Primal Pattern System" of movement, and Stuart McGill identifies them as the fundamental movement patterns. They include changes in the center of gravity, ambulation, manipulation of the extremities and changes in direction.

FOUR BASIC MOVEMENT PATTERNS OF THE HUMAN BODY

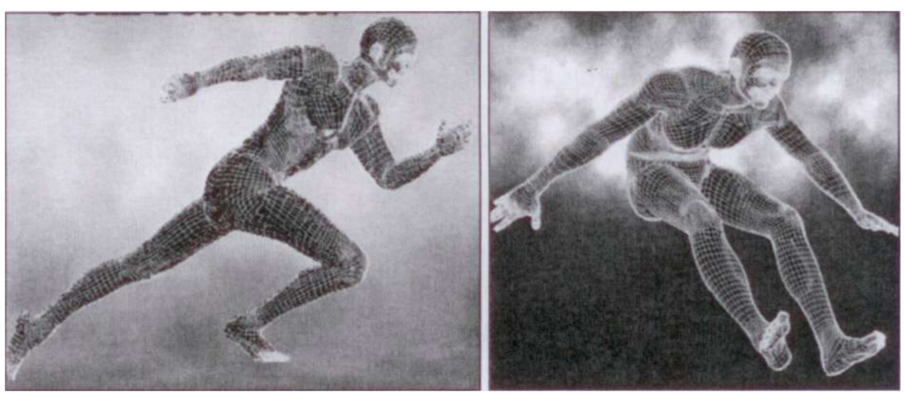
- **Changes in the center of gravity**
  Standing, squatting, lunging, climbing
- **Ambulation**
  Crawling, walking, running, sprinting, stepping, galloping, skipping, hopping, leaping, bounding, jumping
- **Manipulation of the extremities**
  Pushing, pulling, throwing
- **Changes in direction**
  Rotating, twisting, turning, spinning

Changes in the center of gravity. The upright posture of the human body allows us to maintain a center of gravity by distributing our weight across the spine and skeleton. This posture is incredibly efficient and allows us to effectively load our muscles to perform a myriad of motions. From this position we are able to perform squatting which enables us to lower our center of mass to the ground and to lift objects from the ground. The lunging pattern allows us to asymmetrically load our lower extremity to increase our reach, lower our torso toward the ground or maneuver around objects. Using our upper extremities to pull and the lower extremities to push we can move our body up a tree or the side of a mountain, or climb a staircase.



Examples of changes of center of gravity - lunges and squats

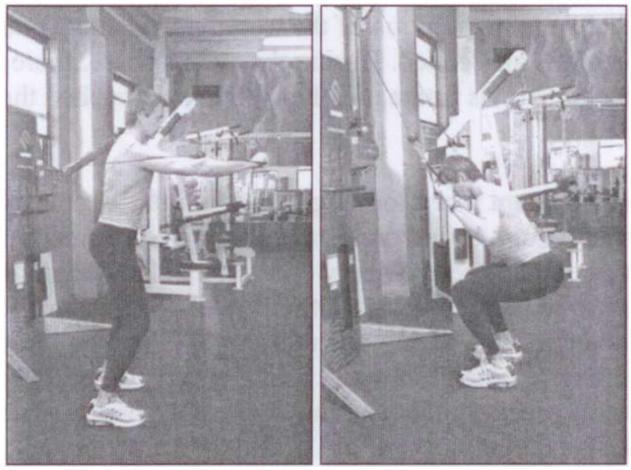
Ambulation. The basic function of our neuromusculoskeletal system is to provide us motion from one place to another. Remember, our goal for thousands of years was to survive, find food, shelter and avoid being eaten. We were often moving from one area of land to another at varying rates of speed. Our neuromusculoskeletal system is highly efficient and adaptable to enable us to transport ourselves in a walking manner or to move at a more rapid pace such as running or sprinting. To cross over larger areas, uneven terrain or to increase our foot placement, we can utilize varying positions of running, skipping, hopping, leaping, bounding and jumping.



Examples of ambulation - running and horizontal jumping

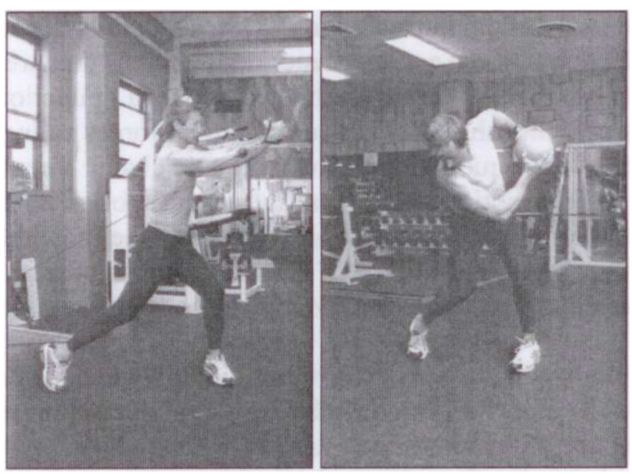
Manipulation of the extremities. By manipulating our extremities, we can perform a myriad of tasks such as lifting and carrying in addition to innumerous fine motor tasks. While muscles can only perform pulling motions, by utilizing the skeleton as a lever system, they are capable of performing pushing motions. Pulling motions allow us to bring objects into our body for greater ease in lifting and carrying. Pushing motions allow us to move objects away from our body either by lifting them onto another surface or by accelerating them, as seen in throwing. Our body commonly works in a cross pattern where one extremity is pulling while the opposite one is pushing, as seen in

walking, running or throwing an object. The contralateral forces act to cancel each other, thus allowing us to maintain our center of gravity.



Examples of manipulation of extremities - pushing and pulling

Change in direction. The fourth and final basic movement pattern is perhaps the most important. It includes changing of direction, which we perform through rotation and twisting. This motion allows us to move our body perpendicular to the force of gravity. Through the summation of forces that are generated by the varying regions of the core musculature, we are able to accelerate and decelerate our bodies or an object, as seen in throwing. Additionally, we are able to perform a limitless number of complex movements by rotating and adjusting our limbs and trunk.



Examples of changes in direction - rotation and twisting

It is important to keep these basic movement patterns in mind when designing core training and rehabilitation programs for the core. It should become obvious after studying the four basic movement patterns that our body is meant to move by combining movement in all three planes of motion, across all the joints of the kinetic chain, at varying levels of speed and with the right amount of control.

All movements can be broken down into components or "chunks." Even a complex move such as swinging a golf club is a combination of several movement patterns. During the address, there is a change in the center of gravity as the hips are flexed. During the backswing, there is a change in direction of the trunk, pelvis and a pulling of the extremities as these regions are loaded. During the swing phase, there is an unloading of the forces as the trunk and pelvis rotate and the club is now pushed through by the extremities.

It should also become apparent when looking at the four basic movement patterns the body never works in isolation. It functions in an integrated manner by selecting various movement patterns rather than preferentially choosing isolated regions or muscle groups. The body doesn't like to work in isolation - it will work to distribute force across as many joints as possible to reduce stress to any one region. This will be the basis of functional training: involve as many muscle groups and joints as possible and teach the body to integrate the movements precisely the way they were designed. A final point when taking this view of movement is that as trainers and health care practitioners, we must be looking at the whole kinetic chain when trying to enhance performance or improve causes of dysfunction. Dysfunction anywhere along the kinetic chain can impact distal structures and, therefore, have significant affects on the overall functioning of the neuromusculoskeletal system.

Functional Biomechanics: Pronation and Supination

A brief introduction and understanding of biomechanics is necessary to appreciate how the experts have developed a functional training and rehabilitation paradigm. **Biomechanics** is the study of the intrinsic forces (forces that are generated within the body such as muscle contractions) and extrinsic forces (forces that are generated outside the body such as gravity) that are acting on the kinetic chain. Functional biomechanics addresses the intricate relationship between joint motion, forces acting upon the joint and muscle action related to those motions within the kinetic chain. Simply put, functional biomechanics looks at how motion at one joint influences motion on the rest of the kinetic chain. While the study of biomechanics is beyond the scope of this book, an understanding of the biomechanical terms of pronation and supination are essential to understanding the complex functioning of the hip and lower extremity.

The motions of pronation and supination have traditionally been taught in regards to motions that occur at the elbow and ankle/subtalar joints. Pronation at the elbow involves turning the palm from a neutral or anatomic position to a palm facing the floor position. Supination is turning the palm up from either a pronated or neutral elbow position. Pronation and supination of the ankle/subtalar share a similar end product with the wrist in that the sole of the foot moves into the ground in a medial direction during pronation and moves off the ground in a lateral direction during supination. The difference with the ankle is the ankle, in conjunction with the foot, is going through tri-planar movement as it accomplishes those motions. During pronation, the ankle and foot move through sagittal plane (dorsiflexion), frontal plane (eversion) and transverse plane

(abduction) motions. Supination will have the foot moving through sagittal plane (plantarflexion), frontal plane (inversion) and transverse plane (adduction) motions.

Gary Gray, one of the pioneers of functional training expanded the concepts of pronation and supination to include all the joints in the kinetic chain. He describes **pronation** as a position in which a series of joints in the kinetic chain are coming under **load** in order to **decelerate** the body. **Supination** is then described as a position where the same series of joints are being **unloaded** and reacting to being loaded in order to **accelerate** the body. The end product of supination will then be pronation or loading of theses joints in preparation for the next move.

Most Joints Move in Three Planes of Motion

Traditional anatomy teaches us that motion in many joints such as the knee and elbow is limited to two planes of motion. The knee moves through sagittal (flexion and extension) and transverse (internal and external rotation) planes of motion. The elbow moves through similar planes but rotation at the elbow is referred to as pronation and supination. If you view the body in anatomical position, both joints demonstrate a normal valgus position. If we look at the knee as it moves into flexion during the gait cycle, we see the tibia moves into a more lateral or valgus position. As the knee extends, the tibia moves more medial and the knee joint is moving varus in direction. While we can't necessarily use muscle contraction to move the joint into these positions, the design of the joint allows movement through the coronal plane.

The tables below outline the multi-planar motion at the hip, knee and ankle/foot complexes.

HIP	***Sagittal***	***Frontal***	***Transverse***
Pronation	Flexion	Adduction	internal rotation
Supination	Extension	Abduction	external rotation

KNEE	***Sagittal***	***Frontal***	***Transverse***
Pronation	Flexion	adduction (valgus)	internal rotation
Supination	Extension	abduction (varus)	external rotation

ANKLE and FOOT	***Sagittal***	***Frontal***	***Transverse***
Pronation	dorsiflexion	eversion	abduction
Supination	plantar flexion	Inversion	adduction

The Hip

ARTICULATIONS	TYPE OF JOINT
Coxafemoral (femur and acetabulum)	Enarthrodial (ball and socket)

JOINT MOVEMENTS	RANGE OF MOTION
Flexion	120-135°
Extension	30°
Abduction	40-45°
Adduction	20-30°
Internal rotation	40-45°
External rotation	40-45°

The hip joint is an important component of the kinetic chain and functions to statically and dynamically support the weight of the upper body as well as absorb ground reaction forces. Due to the high demand placed upon the hip joint, especially during unilateral stance, the hip joint relies on several factors for its stability. These include:

SUPPORT OF THE HIP JOINT

- **Shape of the joint**
- **Ligamentous support**
- **Muscular support**

The hip joint is a true ball and socket articulation as the head of the femur firmly rests in the acetabulum of the pelvis. The hip "socket" is enlarged by the labrum that surrounds the head of the femur as it sits in the acetabulum. The hip joint is attached firmly in place by strong inter-articular ligaments which blend with the joint capsule to provide additional stability of the articulation. Anteriorly, the hip joint is supported by the iliofemoral (also referred to as the "Y" ligament) and pubofemoral ligaments while the ischiofemoral ligament supports the posterior portion of the articulation. While it does provide some minimal support to the hip joint, the ligamentum teres is more important in supporting the blood vessels supplying the head of the femur.

The hip is an important link in the lumbo-pelvic -hip complex and has the responsibility of providing a tremendous amount of stability to the pelvis and lower extremity. The hip joint must be capable of handling loads of two to six times body weight during unilateral weight bearing or while running. Due to these high demands, dynamic stability must come from the muscles that cross the region. Extrinsic stability and gross movement is derived from the "deltoid" of the hip which includes posteriorly, the gluteus maximus, medially, the gluteus medius and anteriorly, the tensor fascia latae. Intrinsic stability is derived from the "rotator cuff' of the hip which includes the gluteus minimus, piriformis, obturator externus and iliacus.

The axis of rotation of the hip joint is located lateral to the downward force of the bodyweight and therefore significant lateral stabilization is required to maintain the

pelvis at a level height. Recall the anterior oblique (external oblique, contralateral internal oblique and contralateral adductors) and lateral (gluteus medius and minimus, tensor fascia latae, contralateral adductors) stabilization chains are the primary frontal plane stabilizers of the hip. Weakness or decreased neuromuscular control of these chains will result in an unleveling of the pelvis or cause a compensatory shift of the torso over the weight bearing leg during unilateral weight bearing. This is referred to as a positive Trendelenburg sign. Chronic presentation of a Trendelenburg sign (Trendelenburg gait) may lead to degenerative changes of the hip, shearing of the sacroiliac joints and potentially create low back and knee pain.

Frontal Plane Functional Biomechanics

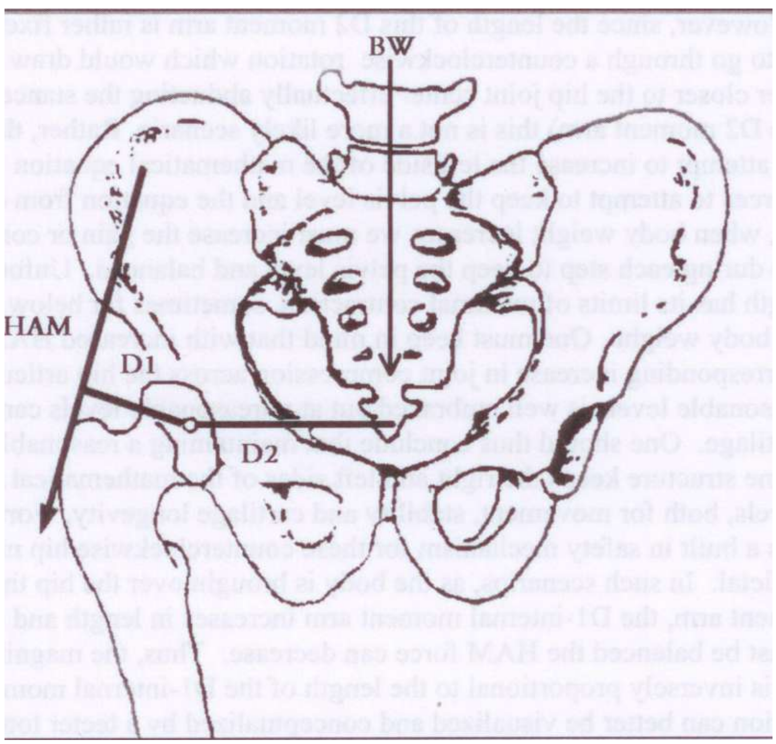
The hip is a very complex joint. It is a ball and socket joint with great stability and potentially great mobility. Its normal function enables unrestricted movement in all ranges. Every movement of the head of the femur in the acetabulum (open kinetic chain function) and every movement of the pelvis on the femur (closed kinetic chain function) is determined by the synchronous activation of the prime mover or agonist and its synergists with control, joint centration and joint stability assisted by the antagonistic muscle group. This is not to ignore the paramount activation of the other cardinal stabilizers surrounding the joint, particularly when engaged in a functionally dynamic closed kinetic chain movement. Gait observation is the most simple in viewing the open and closed chain functions. In the stance phase the hip joint is in the closed chain with the acetabulum rotating around the relatively static femur while the swing phase is characterized by the head of the femur rotating within the more static acetabulum.

One of the most critical and essential planes of motion and stability is the frontal plane of hip joint motion. This plane (coronal/frontal) of motion and stability is largely determined by the hip abductor muscle (HAM) group through an axis of oriented in the anterior-posterior direction through the head of the femur. The most obvious and simple function of the hip abductor muscles is to produce a movement or moment of abduction of the femur in the acetabulum in the frontal/coronal plane (as in a side lying leg lift). As mentioned, this is a simple way to determine open kinetic chain range and open chain strength in this range but it is neither true nor transferable in theory or practicality when the foot is on the group. When the foot engages the ground the typically usable functional range is much less and the muscular function is now to move the pelvis on the stable and somewhat static femoral head in the frontal plane. Explained in another way, in this closed chain, the insertion of many muscles remains static and the force generated through the muscle will pull at the origin and generate movement at the joint in this manner. In a nutshell, the hip abductor muscles (HAM) will produce either leg motion to the side (abduction) or it will produce a lateral bending or lateral flexing of the pelvis-torso into the same range of motion (abduction).

The most critical and commonly considered hip abductor muscles (HAM) are the gluteus medius, gluteus minimus and tensor fascia lata-iliotibial band complex. These muscles have the most favorable line of pull and all have a femur and pelvis attachment. We will call these muscles collectively the HAM group. In the stance phase of gait the body's center of gravity (COG) is medial to the hip joint axis of motion. Thus, in this single leg support phase of gait the tendency will be for the body mass above the hip to rotate or drop towards the swing leg side. This gravitational movement should be offset by the concentric, isometric and eccentric muscular activation of the HAM group through the anterior-posterior oriented axis through the head of the femur. Any functional strength deficits (concentric, isometric or eccentric) of the HAM group and/or neighboring synergistic stabilizers will result in an altered joint stability challenge because not only do the HAM and surrounding muscles product movement but they also generated joint compression and thus stability. The possible undesirable outcome may be an altered

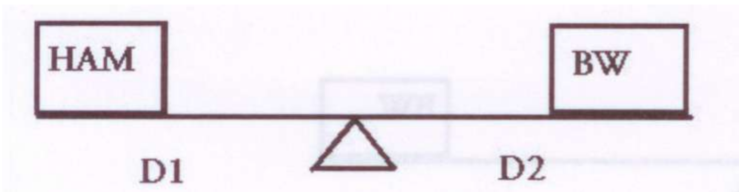
movement patterning characterized by inappropriate muscle or muscle group activation in either timing, force, speed or coordination with typically coupled muscles. These challenges to the joint and its normally expected movement patterns will result in the body's search for more stable positions in the frontal, sagittal or oblique planes. These newly established, yet less efficient, positions and patterns of movement are initially welcomed compensations but in time as the new accommodations become rooted in pattern the synergists and other recruitments become overburdened and further demand compensations from other neighboring muscles eventually resulting in pain, joint derangement and dysfunction. These compensations in recruitment and movement eventually will lead to non-contractile soft tissue changes such as hip capsule pattern changes in tension and length. These non-contractile soft tissue changes can not only dictate or perpetuate the newly established aberrant joint movements but help engrain the abnormal movement patterns and their new neurologic patterns.

Figure 1 shows the condensed version of the parameters (forces and moment arms) affecting movement and stability of the femur-acetabulum complex in the frontal plane during the closed kinetic chain. (A moment arm such as D1 and D2 is defined as the length of a line that extends from the axis of rotation to a point of right angle intersection with a respective force, in this case HAM or BW.)



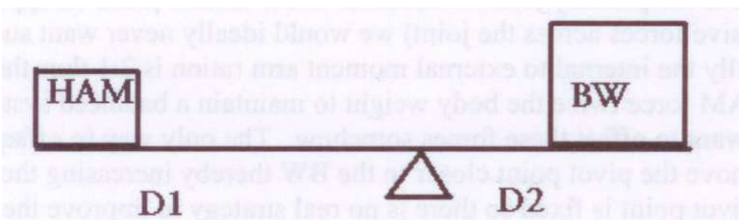
In Figure 1 above we see several parameters. HAM represents the Hip Abductor Muscles, D1 represents the internal moment arm, D2 represents the external moment arm and BW represents the Body Weight of the individual. These factors all come into play when considering the frontal plane equilibrium of the hip joint. The equation representing the interaction of all of these parameters is HAM x D1 = D2 x BW. Both sides of this equation must be equal and balanced in order for the pelvis to remain stable and without movement when in the closed chain stance phase of gait. In this diagram, if the left side of the equation is greater than the right the net effect will be a counterclockwise hip moment and the patient will move their torso over the hip creating a hiking or lifting of the contralateral hip. This net movement will create abduction at the hip joint. If the right side of the equation is greater than the left the net effect will be a clockwise hip moment and the patient will move their torso away from the hip creating a dropping of the contralateral hip. This net movement will create adduction at the hip joint seen here and thus the classic Trendelenberg gait. We need to keep in mind that this is not a perfect model presented here since we are ignoring acceleration of the body in the forward sagittal plane and rotational planes. Investigating the equation further should bring the reader to further realization that if the body weight (BW) were to increase, mathematically the D2 external moment arm could decrease to keep the equation balanced. However, since the length of this D2 moment arm is rather fixed (unless the pelvis were to go through a counterclockwise rotation which would draw the body weight center closer to the hip joint center effectually abducting the stance hip, thus reducing the D2 moment arm) this is not a more likely scenario. Rather, the response would be to attempt to increase the left side of the mathematical equation thus increasing the HAM forces to attempt to keep the pelvis level and the equation from changing. In other words, when body weight increases we must increase the gain or contraction in the HAM group during each step to keep the pelvis level and balanced. Unfortunately the HAM strength has its limits of maximal contraction, sometimes far below any major increases in body weight. One must keep in mind that with increased HAM contraction there is a corresponding increase in joint compression across the hip articular surfaces which at reasonable levels is well embraced but at unreasonable levels can damage articular cartilage. One should thus conclude that maintaining a reasonable body weight for one's bone structure keeps the right and left sides of the mathematical equation at tolerable levels, both for movement, stability and cartilage longevity. Fortunately the equation has a built in safety mechanism for these counterclockwise hip moments, one that is beneficial. In such scenarios, as the body is brought over the hip thus decreasing the D2 moment arm, the D1-internal moment arm increases in length and since the equation must be balanced the HAM force can decrease. Thus, the magnitude of the HAM force is inversely proportional to the length of the D1-internal moment arm. The whole equation can better be visualized and conceptualized by a teeter totter diagram with a sliding pivot point.

Figure 2



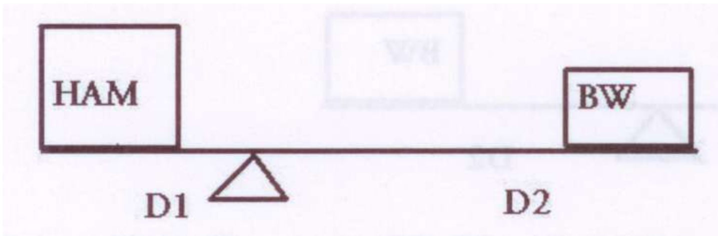
This diagram shows a balanced HAM x D1 = D2 x BW equation. The HAM equals the BW so the pivot point is half way and the lever arms are equal.

Figure 3



This diagram also shows a balanced HAM x D1 = D2 x BW equation. The BW is larger than the HAM but this is offset in the rules of the teeter-totter. Shifting the pivot point towards the larger mass is offset by the smaller D2 and larger D1 moment arms. This is a typical compensatory mechanism used by obese patients to ambulate effectively. It does render significant frontal plane movement of the pelvis instead of the more desirable silent frontal plane pelvis. In this compensation, even large body weights can be somewhat offset by the degree of contralateral hip hiking to reduce the D2 moment arm and increase the D1 moment arm however this compensation has its limits. When the limits of alteration of moment arm length are reached the body's only compensation at that point is to increase the HAM forces which increases joint compression and thus cartilage wear since the cyclical loading and unloading of the cartilage is much less. This is also the same mechanism used by patients with a osteoarthritic painful hip joint. We are not referring to increasing BW, rather we are suggesting that to reduce pain the patient will want less joint compression and thus a reduced HAM. To do this we want to increase the D1 moment arm. The only way other than surgery to achieve this increase in D1 is to take the existing body weight and shift it closer to the pivot point. Ideally you would want to lean so far over the affected painful hip as to get your body weight (BW) immediately over the pivot point. This would effectively reduce D2 to nil and significantly increase D1 thus allowing HAM to be minimal; thus reducing painful joint compression. (In teeter-totter verbiage, put the small child on the long part of the teeter-totter arm and you can move large forces with little effort at the pivot point.)

Figure 4



This diagram also shows a balanced equation; HAM x D1 = D2 x BW. This is not exactly a desirable scenario or strategy to obtain when it comes to joint compression mechanics however it is close to representing what is accurate in the human hip. Since the gluteus medius muscle is the primary joint compressor in the frontal plane (it applies two thirds of the compressive forces across the joint) we would ideally never want such a large HAM force. Typically the internal to external moment arm ration is 2:1 thus this model would require a HAM force twice the body weight to maintain a balanced system. None the less, we would want to offset these forces somehow. The only way to offset the large HAM would be to move the pivot point closer to the BW thereby increasing the D1. In a physical person the pivot point is fixed so there is no real strategy to improve the situation without surgery. These patients are unlucky and have no strategies to improve their high compression forces unless they loose weight; due to the fact of the 2:1 ratio, for every pound of body weight loss there is a 2 pound force decrease in the HAM.

As mentioned previously, the model presented is very much incomplete. Muscular forces surround the joint, movement occurs in every cardinal plane and there is acceleration of body segments which requires even greater muscular contraction isometrically, concentrically and eccentrically. These factors all considered, it has been calculated that the total hip force crossing the joint can reach 3 times the body weight during walking. This force is welcomed for maintaining joint stability but it can be an unwelcome force in a degenerative arthritic joint where the cartilage is less pliable and flexible. The loading forces in an arthritic joint rhythmically pass into the acetabulum and femoral head as a result of the compromised cartilage necessitating increased bone mass and sclerosis within them. This compromised arthritic joint will have some minor laxity due to the loss of the cartilage bulk and thinning of the acetabular labrum. Thus the joint will have a slight increase in translatory movement and require greater muscular contraction to minimize these movements. These increased forces will be unwelcomed as they will generate more pain. Additionally, the increased movements and degenerative debris within the joint will cause irritation and inflammation of the joint capsule and synovial lining causing further pain. This entire scenario will cause the patient to investigate conscious and subconscious gait strategies to reduce the compression across the joint, in other words, they will essentially seek gait strategies that will reduce HAM (gluteus medius contraction) and increase the D1 internal moment arm. These strategies will reduce the perpendicular joint compression forces that likely will be causing pain but if performed well they will be devastating to the normal frontal plane equilibrium since the

gluteus medius muscle will be essentially shut down and inhibited. Thus, the patient's gait strategy will give us the compensated Trendelenburg gait pattern. The uncompensated Trendelenburg gait will show a dropping of the contralateral hemipelvis on the swing side during gait, this is the pathologic gait pattern we see when the patient has not implemented strategies to reduce their pain but it is more likely seen when the patient is not yet at the painful stage in which they need to implore strategies to avoid the movement. Comparatively, compensated Trendelenburg gait pattern will display a lifting of the contralateral hemipelvis. This strategy is not implemented by activation of the gluteus medius on the side in question, rather it is a compensation move performed by shifting the patient's body weight over the pathologic hip thus causing the hip that is dropping to be passively raised into a more normal range in the frontal plane. This passive frontal plane move by the patient over the painful hip is at first difficult to embrace logically as one does not expect to want to load their body weight further over top of the painful hip. However, upon investigation of the mathematical equation one will see that the shift of body weight (BW) over the affected hip will significantly reduce the D2 external moment arm, significantly increase the D1 internal moment arm and thus deliver us the desirable significant reduction in the HAM gluteus medius compressive contraction across the painful hip. Thus, the pathologic compensation gait pattern in the frontal plane will markedly reduce the patient's hip pain. From a kinetic chain perspective however, there is always a price to pay. This implemented strategy of ipsilateral trunk lateral flexion is performed by utilization of the thoracolumbar paraspinals and quadratus lumborum on the painful hip side. The resulting abnormal muscular and joint strategies now imparted on the lumbar spine and pelvis interface frequently begins a cascade of muscular and joint pain in the low back and abnormal loading of the lumbar discs. The strategy also begins an unwelcome increased loading of the non-painful hip as the patient is loading the hip greater than normal due to the height from which the hip and pelvis drop from the compensated Trendelenburg position. In other words, by protecting the painful arthritic hip from increased loads we sacrifice the healthy hip for a period of years until the forced finally amount to enough damage that pain begins here as well. Fortunately, we have the ability to mediate some of these dramatic movements and forces by using logic and a cane. By placing a walking cane in the hand opposite to the painful hip and by asking the patient to contact the cane with the ground when they initiate contact with the painful limb we can offset some of the excessive compensations and forces. When the cane contacts the ground the patient is to apply a mild to moderate downward force through the cane via arm contraction. This downward force will afford us a resultant upward ground reactive force through the cane delivering us a lifting effect on the dropped hemipelvis side (dipping hip side/non-painful side). This strategy will allow us a more passive shifting of the body weight (BW) over the painful hip side without having to lift or pull the body weight (BW) over the painful hip with the hip abductor muscles (HAM). These passive forces (which can be more than half of those normally needed to be generated by the HAM) will help to markedly reduce the muscular forces needed by the spinal and quadratus muscles while also rendering the desired marked reduction in HAM compressive forces across the painful joint. It is interesting to note that the further the cane is placed from the body, the longer its moment arm and thus the less downward force necessary by the patient's arm. It is quite possible, that if used correctly, a cane can almost completely offset the required contralateral HAM

force. Another passive strategy would be to carry objects (purses, books, grocery bags, etc) on the affected hip side. This action will also balance the teeter-totter in favor and thus reduce the muscular forced necessary to perform the same task. It must be noted however that increasing any body load is undesirable and should be avoided not so much because of issues pertaining to the painful degenerative hip but because of the increased load on the healthier hip.

Sagittal Plane Functional Biomechanics

Thus far we have discussed the hip biomechanics mostly in the frontal plane. The sagittal plane mechanics are much less complex since the axis of movement is in the frontal plane (the axis is directed horizontally through the femoral heads and pelvis) and the body weight for the most part rests on this same plane (unlike the frontal plane mechanics where the body weight is a moment arm away from the center of the hip rotation). One of the main reasons the mechanics are a little less complicated for the most part is due to the fact that even with the pelvic obliquity that occurs during gait cycles of swing and stance, the body weight still remains largely over this trans-femoral head axis.

In the sagittal plane the prime movers are the iliacus/psoas complex and gluteals (flexion and extension of the hip respectively). The hip flexor synergistic muscles are the quadriceps and abdominals while the hip extensor synergist is mainly the hamstring group. This is certainly simplified since transaxial rotation through a vertical oriented axis does occur as a coupled motion and thus we cannot talk about sagittal plane movements, or even frontal plane movements for that matter, without at least considering the effects of movement generation or stabilization by the hip intrinsics (gemelli, oburators, quadratus femoris, piriformis).

The greatest body function in the sagittal plane is gait and many of the body's compensations and conditions stem from alterations in hip joint function through this movement negotiation through the sagittal space. For the therapist, clinician or trainer the greatest problem can be the body's numerous back up systems which compensate and share normal or abnormal loading.

The basis of gait evaluation needs to be based from a holistic perspective. Gait cannot be evaluated without consideration of the entire organism. A minor functional limitation in the first metatarsophalangeal (MTP) joint can significantly impact hip, pelvic and spinal biomechanics. The best and simplest example of this is the clinical scenario of hallux limitus. We will entertain the equally devastating functional hallux limitus later on in the chapter but the point to note here is that a minor loss of the last few degrees of the normal MTP joint dorsiflexion (45-60 degrees is necessary, patient specific) can be devastating to sagittal plane motion of the body. Even a loss of the last 5 degrees of this normal range, although appearing relatively normal on an examination and possibly without symptoms (ie. early stages of progression into a more noticeable hallux limitus), can impact normal and efficient toe off. If toe off is early, even to a small degree, then the

stance phase will be abbreviated via early heel rise. If heel rise is early this creates a functional change in the kinetic chain, both open chain and closed chain. There are many closed chain changes that will occur. One such change might be toe off propulsion forces being imparted through a more flexed tibiofemoral joint (knee) which will impart both translatory shear forces in the sagittal plane and torsional forces through the joint, both causing potential maceration effects on the menisci. However, perhaps the easiest functional changes to understand are the changes at the hip. It is well known on EMG studies that hip flexion is both an active and passive motion during gait. The active flexion of the hip is generated largely by iliacus/psoas concentric contraction. However, this is not the first mechanism to generate hip flexion. In fact, hip flexion is first generated passively through engagement of the kinetic chain. The first movement of the swing phase is rotational or torsional activation of the oblique pelvis through core

activation of the abdominal muscle group. Through activation of the internal and external abdominal obliques and transversus abdominus, in addition to activation of their synergists and cocontration of their antagonistic stabilizers, the obliqued pelvis is rotated. Better said, the trailing leg's lagging pelvis is moved forward by contract of the synergistic oblique activation. This forward movement generates a sagittal momentum and movement of the toe off leg. Once movement is generated then the iliacus/psoas activates concentrically to perpetuate hip flexion. In other words, the iliacus/psoas is not an initiator of hip flexion, rather, a perpetuator. When hallux limitus limits the stride length via early generation of heel rise the pelvic obliquity is limited. As a result, the degree of initial swing phase leg movement is less from the generation of pelvis de-rotation via abdominal activation and more through ill-directed iliacus/psoas hip flexion. Thus, as hip flexion still needs to occur, the iliacus/psoas is called upon to compensate; it now becomes a hip flexion initiator as well as its previous function of hip flexion perpetuator. This demand is minimal but with repetitive demand thousands of steps per day, the iliacus/psoas eventually looses its ability to continue these compensations, as does its now over burdened synergists. The result is either hypertrophy, inhibition, hypertonicity, spasm, shortening, insertional tendonitis, origin tendonitis or a combination thereof but make no mistake, such burden will eventually cause dysfunction within the muscle itself or within its synergists or antagonistic pair. The scenario may result in either joint dysfunction at the lumbar spine near the muscle's origin, at the sacroiliac joint over which it crosses, or at the hip joint proper. The ensuing joint derangement or dysfunction is complex and creates numerous compensation patterns locally and globally since the main function of the muscle is to create hip flexion, external rotation, and abduction in the open kinetic chain and trunk flexion and trunk internal rotation in the closed kinetic chain. In a nutshell, the loss of dorsiflexion of the hallux, even to a minor degree, must be made up somewhere in the sagittal plane. If it is not immediately made up for at the more proximal joints (1^{st} metatarsal-midfoot joint, talo-navicular, ankle mortise-tibiotalar, or knee) the hip will undoubtedly change its function as described above to compensate, it is well suited to do so. Keep in mind that such compensations may be better suited at the ankle, knee or hip depending on the degree of hip ante/retrotorsion or tibial internal/external torsion if present but none the less these compensations have consequences to changes in function of muscles either eccentrically, isometrically or concentrically or by recruiting assistance from synergists or antagonistic groups. Additionally, a person with a very flexible midtarsal joint may

stop the more proximal compensations via restoration of the necessary first ray (first toe) complex dorsiflexion at that more immediately proximal joint complex.

A **Piece of the Functional Puzzle: Hip Rotation**

As we have already mentioned, stabilization of the hip is complicated in its own right, but when we ask it to participate in balanced single limb movement in the frontal/coronal, sagittal and axial planes all at once the delicate balancing act of stability while enabling mobility through movement is sheer genius on any level.

Through our collective clinical experiences it has become apparent over time that vertical and horizontal gravity dependent postural examination can open insight into a deeper functional disturbance in patients. For example, an externally rotated right lower limb as evidenced by an accentuated external foot flare should initiate the thought process that there is either an anatomically short right limb (external rotation increases leg length), tight right posterior hip capsule, short gluteals or other posterior hip musculature (piriformis, obterators, gemelli) or an over-pronating right foot which shortens the limb and hence the need for the externally rotated and lengthened right limb. In consideration of all scenarios, our traditional thinking has directed us to believe we are dealing with a limb posture that has occurred to lengthen the limb in question. However, perhaps the compensation is deeper in its root cause. For example, the traditional thinking in alignment restoration of this postural deviation is to stretch the piriformis, glutes and iliacus/psoas and perform deep soft tissue work such as myofascial release methods, stripping, post-isometric release and mobilization or manipulation to the affected tissues and associated joints to ensure normal function. These efforts are meant to restore the limbs rotational anomaly and hopefully the cause of the leg length compensation. However, many clinicians will attest to the fact that these methods are frequently unsuccessful or at least limited in their short or long term effectiveness towards complete symptom and postural deficit resolution. Frequently our patients enter into the cyclical office visits several times a year to address symptoms associated with the root cause. Thus, we must delve deeper into the source of the problem. This will require the therapist to investigate the open and closed kinetic chain functions of these external and internal hip rotators and look further and more deeply for the source.

In the open kinetic chain (swing phase of gait) the primary and secondary external rotators turn the lower limb outwards in relation to a fixed pelvis established by a sound core; this is late swing phase. In the closed kinetic chain scenario, with the foot engaged with the ground, the activation of these same muscles will cause the same movement at the hip-pelvis interface but in this case the pelvis/torso will rotate. For example, in observance of a closed chain right lower limb, upon activation of the glutes, piriformis and accessory external hip rotators the client's pelvis and thus torso will rotate to the left (counterclockwise rotation) along the vertical body axis about the fixed right limb. With this functional thinking we must now embrace the fact that our traditional perspectives of body function assessment in the frontal and sagittal planes must be largely discarded. It is a rare occurrence that we move in a single plane of motion without any component of

rotation. This being accepted, we must return to our client's left pelvis rotation and understand that torso rotation must occur in the opposite direction if gait is to be normal with proper arm swing and propulsion. This rotation can occur from activation of not only component muscles at the hip-pelvis interval but also from the abdominal obliques, thoracic spine and rib cage. Therefore, one could hypothesize that a client's external rotation of the right lower limb in stance or gait might not be a primary problem with the piriformis, glutes or accessory muscles rather it could be a compensation for either a one sided over-active or weak abdominal oblique system or abnormal thoracic rotation, or a combination of both. Assessment of a patient's passive and active torso and thoracic/rib rotation might open a window into one of a range-driven deficit or weakness/inhibition. The practitioner must always embrace the thought that the client's core might not only present as weak but to a higher level that of imbalanced, which is a combination of weakness, stretch weakness, strength, over-activation and inhibition. This imbalance can come from such parameters as pain, handed dominance activities, lower limb dominance issues, occupational demands or others as discussed below.

What we continue to find as our clinical experiences expand is that most deficits in the body are driven by a functional core weakess/imbalance or forces not dampened across a weak core. In this case, the absence of balanced core abdominal strength and torso rotation renders a weaker or inhibited core rotation on one side and it is this deficit that is compensated in the pelvis as a tight hip/pelvis soft tissues unilaterally (expressed perhaps as the unilateral externally rotated limb). Taking the example above, a right externally rotated lower limb with associated tight and/or painful right piriformis muscle, we frequently see a loss of rotation range or strength into left torso rotation. This scenario might be showing little to no progress with therapy. Therapeutically facilitating oblique abdominal strength to improve range and strength into left thoracic/rib cage rotation quite frequently over time will reflexively reduce the piriformis spasm and rotational deficit in the right lower limb without even applying much direct therapy to this area. In other words, our experience shows that improving the thoracic rotation into the side of limitation should have some neurologic response of inhibition/relaxation on the piriformis. We would be amiss if we were to neglect that this oblique abdominal weakness could coincide with a slight anterior pelvic tilt in the sagittal plane on that side. We would see a slight bellowing of the left abdominal group and a slight increased anterior pelvic tilt on the same side. This asymmetrical pelvis posture would load the superior aspect of the right piriformis and force it into spasm due to the sustained pelvic obliquity and slight drop in the anterior direction. This spasm can inhibit the gluteal group and further complicate the problem. Keep in mind that a weak left oblique abdominal system would facilitate a tendency towards a sway back position, stretch weak left iliacus/psoas, and the anterior femoral glide syndrome of the hip. As previously touched upon, activities of daily living such as sleep, stance and sit positions, driving style, handedness, respiration, functional and anatomical leg length differences, unidirectional floor transfers and simply imbalances in the hip rotators can all cause this imbalance and thus piriformis dysfunction. In summary, the key to the body in the above scenario is in its ability to create and control rotation. The ribs, thoracic spine and hips are the most important rotators of the body and their relationship is direct. Our examination methods are traditionally focused on the sagittal and frontal planes, however

these can only be sound and proper if rotation is pure and uninhibited. Even something as simple as respiration mechanics can be dysfunctional as a result of excessive computer use, reading, driving, sedentary lifestyle and sporting history (one sided dominant sports. For these reasons, most individuals will be unable to rotate effectively and without compensation patterns so the rotational deficits frequently are expressed either upwards into the thoracic spine, ribs and shoulders (one way to see these problems is to look at shoulder posture and arm swing during gait) or they are expressed caudally into the pelvis at the hips.

The Knee

ARTICULATIONS	TYPE OF JOINT
Tibiofemoral	Ginglymus (modified hinge)
Patellofemoral	Arthrodial (gliding)
Tibiofibular	Syndesmosis

JOINT MOVEMENTS	RANGE OF MOTION
Flexion	130-150°
Extension	0-10° (hyperextension)
Internal rotation	20-30°
External rotation	30-40°

The knee joint is the largest synovial joint in the body and is classified as a modified hinge joint because it allows for rotation in addition to flexion and extension. While it is often not mentioned, the knee also has frontal plane motion (valgus and varus) during the normal biomechanics of the gait cycle. Although knee injuries are rampant in our society, the knee is a relatively stable joint. It derives this stability from the shape of the articulation, numerous ligamentous attachments and the dynamic stability supplied by the large muscle of the hip and thigh.

SUPPORT OF THE HIP JOINT

- **Shape of the joint**
- **Ligamentous support**
- **Muscular support**

The knee joint is formed by the femoral condyles articulating with the tibial plateau. While this design is inherently unstable, the menisci conform to the femoral condyles and function to increase the stability of the joint. Strong medial and lateral collateral ligaments provide frontal plane stability to the joint against valgus and varus, respectively. The anterior cruciate ligament (ACL), which arises from the posteromedial aspect of the lateral femoral condyle and inserts into the tibia near the anterior tibial spine, provides stability against anterior migration and internal rotation of the tiba. The posterior cruciate ligament (PCL), which arises from the anteromedial aspect of the medial femoral condyle and inserts into the tibia near the posterior tibial spine, provides stability against posterior migration of the tibia. While these ligaments are adequately strong and durable, they are extremely vulnerable to rotational forces that occur during the loading phase of gait and during changes in the direction of movement (planting of the foot accompanied by a rapid change in the direction of the momentum of the body). Therefore, the integrity of the knee is heavily reliant on the dynamic support provided by the powerful muscles of the hip and knee regions.

Dynamic stability of the knee is achieved through the numerous muscular attachments that surround the joint. The muscles of the hip are perhaps the most important group of muscles in providing support to the knee.

First is the gluteus maximus (GMx), which is arguably the largest and strongest of all muscles in the body. One can assume from its vast size it plays an important role in the functioning of the kinetic chain. The GMx has the incredibly important task of stabilizing the knee against excessive internal rotation. While the piriformis is often labeled as the primary muscle of external rotation, compare the size and width of the two muscles and decide which one has the easier time performing this task. The GMx has its insertion on both the posterior surface of the femur (gluteal tuberosity) and on the iliotibial band (ITB) which inserts into the anterolateral portion of the tibia (Gerdy's tubercle). Its oblique fiber direction and insertions onto both the femur and tibia put the GMx in the perfect position to decelerate internal rotation of the knee.

GMx provides the majority of the lateral stabilization of the knee as well. The GMx, along with the tensor fascia latae, insert into the ITB and work as a force couple to dynamically stabilize the lateral portion of the knee. Contraction of the GMx, especially with the hip and knee in flexion, functions to tense the iliotibial band and provide lateral stabilization. The lateral knee is also stabilized by contraction of the vastus lateralis (VL). As the VL contracts, it pushes laterally against the ITB causing the band to become more taut (hydraulic amplifier effect). This increased tension adds to the lateral stability of the knee.

The GMx, by virtue of decelerating internal rotation, also stabilizes the medial knee against valgus stresses placed upon the knee. The knee also derives additional medial support from the muscles that cross the joint, namely the pes anserine group. The pes anserine muscles include the sartorius, gracilis and semitendinosus. These muscles collectively insert into the pes anserine tendon which attaches onto the anteromedial surface of the tibia. They aid the GMx in decelerating internal rotation and valgus stresses to the knee. It has been suggested these muscles have fascial attachments to the vastus medialis obliquus (VMO) and medial patellar retinaculum and therefore aid in the medial stabilization of the patella.

The tibia is dynamically stabilized anteriorly by the quadriceps and the anterior tibialis which has been suggested to have fascial attachments to the patella and patellar retinaculum. Posteriorly it is stabilized by the hamstrings, popliteus and gastrocnemuis.

The patella is a sesmoid bone that acts to improve the mechanical advantage of the quadriceps muscle. The cartilage lining the undersurface of the patella is extremely susceptible to degenerative changes due to the stress put upon it during activities such as walking, running and squatting. Proper tracking between the femoral epicondyles is therefore essential in maintaining the integrity of the cartilaginous surfaces. The Q angle is one method of determining the stress that is placed upon the patello-femoral articulation.

Although theoretical in nature, the quadriceps angle (Q angle) predicts the propensity of the patella to track laterally. The Q angle is an angle formed by drawing a straight line through the long axis of the femur to the midpoint of the patella and from the midpoint of the patella through the tibial tubercle. An increased pelvic diameter (more common in

females), a decrease in the femoral angle and increased genu valgus and pes planus are a few of the factors that create an increased Q angle.

Perpetuating imbalances of the soft tissues of the hip and knee may also set the stage for a potential lateral tracking of the patella. Examples include tightness of the rectus femoris, vastus intermedialis, vastus lateralis, tensor fascia latae, iliotibial band and lateral retinaculum as well as weaknesses of the GMx and VMO and lengthening of the medial retinaculum.

Dysfunctional biomechanics of the lower kinetic chain can also cause and perpetuate patellar tracking problems. An inability to control pronation forces during the loading phase of the gait cycle increases the valgus stress to the knee. This leads to abnormal arthokinematics at the knee joint and the likelihood of degenerative changes occurring at the patello-femoral articulation.

The medial collateral ligament, medial meniscus and anterior cruciate ligament have fascial attachments that bind them together and increase the passive support of the medial knee. The **"unhappy triad,"** also referred to as the **"terrible triad,"** of the knee is a tearing or rupture of these ligaments. This injury usually occurs from a laterally directed force to the knee while the foot and ankle are either planted on the ground or locked in place (as when being tackled). This causes excessive valgus stress on the knee and tearing of the structures. This is also a common injury in skiing when one ski gets "hung up" in the snow and the knee is forced into a valgus and internally rotated position. However, non-contact injuries are equally as common resulting and usually result secondary to faulty biomechanics. Decreased ability to eccentrically decelerate loading forces of the lower kinetic chain during dynamic activities, may directly lead to excessive valgus stress being placed upon these ligamentous structures. Rehabilitation of these injuries must stress eccentric deceleration and stabilization in order to teach the individual to dynamically control these forces on the knee.

In summary, the knee is a relatively stable joint that is "stuck" in between the hip and ankle and is especially vulnerable to altered biomechanics of the kinetic chain. Therefore, when dealing with issues involving the knee, it is important to analyze function along the entire kinetic chain, especially at the hip and ankle.

The Ankle and Foot

ARTICULATIONS	TYPE OF JOINT
Talus/tibia-fibula (crural)	Ginglymus (hinge)
Intertarsal and tarsometatarsal	Arthrodial (gliding)
Metatarsophalangeal	Condyloid (ellipsoidal ball and socket)
Interphalangeal	Ginglymus (hinge)

JOINT MOVEMENTS	RANGE OF MOTION
Plantarflexion	40-50°
Dorsiflexion	20°
Inversion	30-35°
Eversion	15-25°
Pronation (ankle dorsiflexion, ankle eversion, foot abduction)	*
Supination (ankle plantarflexion, ankle inversion, foot adduction)	*

The bones of the ankle and foot form a complex series of joints able to withstand a tremendous amount of stress. Through the complex arrangement of bones, ligaments and muscles, the foot and ankle provide a stable base of support, conformation to uneven ground surfaces, the attenuation of ground reaction forces and allow for the efficient propulsion of the body.

Pronation and Supination

Pronation is a force that enables the body to decelerate or load the muscles for eventual propulsion. At the ankle and foot, pronation includes dorsiflexion of the ankle, eversion at the sub-talar joint and abduction of the forefoot (metatarsals). Pronation allows the ankle and foot to attenuate the shock during the stance phase of gait while also passively pre-stretching the tibialis posterior, gastroc-soleus complex and flexor tendons that act to increase the mechanical advantage of these muscles during the heel-off phase of gait. Supination is a reversal of these movements as the body accelerates or unloads. These motions include plantar flexion of the ankle, inversion at the sub-talar joint and adduction of the forefoot.

Most ankle and foot problems stem from an inability to effectively and efficiently deal with pronation. The ankle and foot sit lateral to the downwardly directed force of the center of gravity and therefore have the propensity to collapse or deviate medially under compressive loads. Several features of the kinetic chain are designed to specifically deal with this pronatory force. At the hip, the powerful gluteus maximus and other external rotators (iliacus/psoas, sartorius, piriformis, gemelli, obturators and posterior fibers of the gluteus medius) are designed to eccentrically control valgus and internal rotation stresses of the lower kinetic chain. At the knee, the medial collateral ligament is thicker and broader than the lateral collateral ligament and contains fascial attachments to the medial

meniscus and anterior cruciate ligament. Additionally, the pes anserine muscles (sartorius, gracilis and semitendinosus) which cross the knee joint aid in the medial stabilization of the knee.

The ankle also has features specifically adapted to handle pronatory forces. The foot has three arches located medially, (medial longitudinal), laterally (lateral longitudinal) and transversely (transverse). The arches form a three point contact at the calcaneus, first ray (first metatarsal) and fifth ray (fifth metatarsal). These arches are specifically designed to support the weight of the body not unlike the way an archway of a bridge supports the weight of several cars. The medial longitudinal, the largest and most significant of the arches, works in unison with the other two in the shock absorption and loading capabilities of the foot. However in order to maintain the integrity of the foot and ankle, the arches require the additional passive and dynamic support provided by the ligaments and muscles respectively.

Several ligaments provide passive support to the medial side of the foot and ankle. First is the deltoid ligament. The deltoid ligament is fan shaped ligament originating from the medial malleolus and inserts into the talus, calcaneus and navicular bones. This powerful ligament aids in the support of the medial tibia, talus and calcaneus. The plantar calcaneonavicualar ligament (spring ligament) attaches from the sustentaculum tali of the calcaneus to the navicular tubercle. This ligament aids in the support of the medial longitudinal arch of the foot.

Another structure supporting the medial longitudinal arch of the foot, as well as the entire dorsum of the foot, is the plantar aponeurosis, more commonly referred to as the plantar fascia. The plantar fascia is a thick band of fascia originating at the base of the calcaneus and extending to all five metatarsals. Although it functions to passively support the dorsum of the foot, dynamic support is needed due to the high stress loads placed upon the medial arch. Decreased ability to decelerate pronation increases the stress upon the plantar fascia. Laxity of the ligaments of the foot, which occurs with excessive weight gain or pregnancy, creates more tension across the plantar fascia. **Plantar fascitis** is often a result of chronic stress placed upon the fascial structures. As the plantar fascia continues to be stresses at its insertion, the body responds by depositing more bone over the insertion (Wolffs Law). This may lead to the development of a heel spur and increased plantar fascia irritation as it rubs across the often sharp osteophyte. While surgery to remove the spur is sometimes indicated, rehabilitation includes stretching out of the tight structures (usually gastrocnemius, soleus and peroneii) and strengthening of the muscles that decelerate pronation.

Several muscles act to decelerate pronation forces of the ankle and foot. Eversion is the frontal plane component of pronation and is eccentrically decelerated by the inverters of the ankle, which include the tibialis anterior and extensor hallucis lonogus. The tibialis posterior is one of the more important muscles that decelerate pronation forces at the ankle and foot. Interestingly enough, it has attachments to the plantar calcaneonavicular ligaments and completely wraps underneath the medial side of the foot to insert into the navicular, cuneiforms, cuboid and bases of second through the fourth metatarsals. Recall

that stretching of ligamentous structures is one of the stimuli that "turn on" the muscles and signal them to decelerate motion. The gluteus maximus must be included in the stability of the ankle and foot since it is the primary muscle involved in decelerating internal rotation of the femur and tibia.

While the medial aspect of the foot and ankle are stabilized rather adequately, the lateral ankle is more susceptible to injuries due to instability. In fact, **inversion ankle sprains** are one of the most common orthopedic injuries seen in hospitals and doctors offices today.

The majority of the passive stability of the lateral ankle is derived from the calcaneofibular, anterior talofibular and posterior talofibular ligaments. Dynamic support is derived from the peroneus longus and brevis and, if present, the peroneus tertius. The peroneus longus wraps around the lateral malleolus, goes underneath the foot and inserts into the base of the first metatarsal and medial cuneiform. It supports the lateral ankle and foot in addition to working as a force couple with the tibialis anterior in stabilizing the first metatarsal. The peroneus brevis inserts into the base of the fifth metatarsal and supports the lateral ankle and foot. The peroneus tertius is an extension of the extensor digitorum which inserts into the base of the fifth metatarsal and aids in dorsiflexion and eversion of the foot.

As is seen with most orthopedic injuries, the lack of proprioceptive input and neuromuscular control are the most likely causes of inversion sprains of the ankle. The proprioceptors of the ankle and foot become dormant with walking on flat surfaces which is so predominant in our society. When the muscles of the ankle and leg are then called upon to decelerate excessive inversion of the ankle as is seen when stepping off a curb, into a pothole or on to an uneven surface, the motor sequences necessary to recruit the proper muscles to decelerate the motion have not been developed. Therefore, proper rehabilitation requires retraining of the proprioceptors in addition to developing eccentric strength of the muscles that control excessive inversion which include the muscles of the lateral chain at the hip and the peroneus longus and brevis at the ankle.

While often not taken into consideration, a pes cavus foot (high rigid arch) can create just as many problems within the kinetic chain as a pes palnus foot (flattened arch). Where the pes palnus foot is usually affected from the top down, the rigid foot often affects the entire kinetic chain. One of the objectives of pronation is to obtain ground contact with as much of the foot as possible. Recall that the goal of pronation is to absorb ground reaction forces and load the muscles that will help to propel the body forward. If the foot is rigid and unable to go through its obligatory motions (subtalar or calcaneal eversion), the body will often compensate by increasing rotation at the knee or hip in an attempt to pronate the foot. A common cause of a pes cavus foot is the inability or a decrease in calcaneal eversion. Remember that the body always seeks the path of least resistance. Thus, there are increased internal rotational stresses placed on the anterior cruciate and medial collateral ligaments at the knee. If internal rotation is increased at the hip, often the piriformis is placed under increased tension. Overuse of the piriformis to aid in the deceleration of internal hip rotation is often a leading cause of piriformis syndrome, a

painful condition characterized by posterior hip pain and sciatica-like symptoms. Rehabilitation of this condition often includes mobilization of the restricted ankle and foot articulations and mobilization/stretching of the associated soft tissue structures.

Anterior tibial stress syndrome, more commonly referred to as **shin splints,** are common orthopedic injuries to runner and dancers. Pain is experienced on the anterolateral side of the tibia and is usually a result of overuse of the anterior tibialis. The most common causes of this syndrome are from tight plantar flexors, especially the gastrocnemius and soleus, and a posterior center of gravity when running, which requires a prolonged dorsiflexion of the foot to clear the toes from the ground during the swing phase of the gait cycle. Correction would include stretching the tight musculature and concentrating on pushing off (plantar flexing) during the terminal stance phase.

Medial tibial stress syndrome (MTSS), more commonly referred to as **posterior shin splints,** is an overuse syndrome affecting the tibialis posterior. MTSS is a strain of the tibialis posterior often occurring as it is eccentrically loaded (over-lengthens) in an attempt to decelerate pronation of the foot. This usually occurs secondary to increased pronation or ankle eversion.

As with the hip and knee, the ankle is an integral part of the lower kinetic chain. Therefore, examination of the entire kinetic chain is essential when assessing dysfunctions of the ankle or foot. Conversely, altered mechanics of the ankle and foot can have effects on the rest of the kinetic chain and will likewise need to be addressed in issues involving the knee, hip and pelvis.

THE INTEGRATED MODEL OF FUNCTION

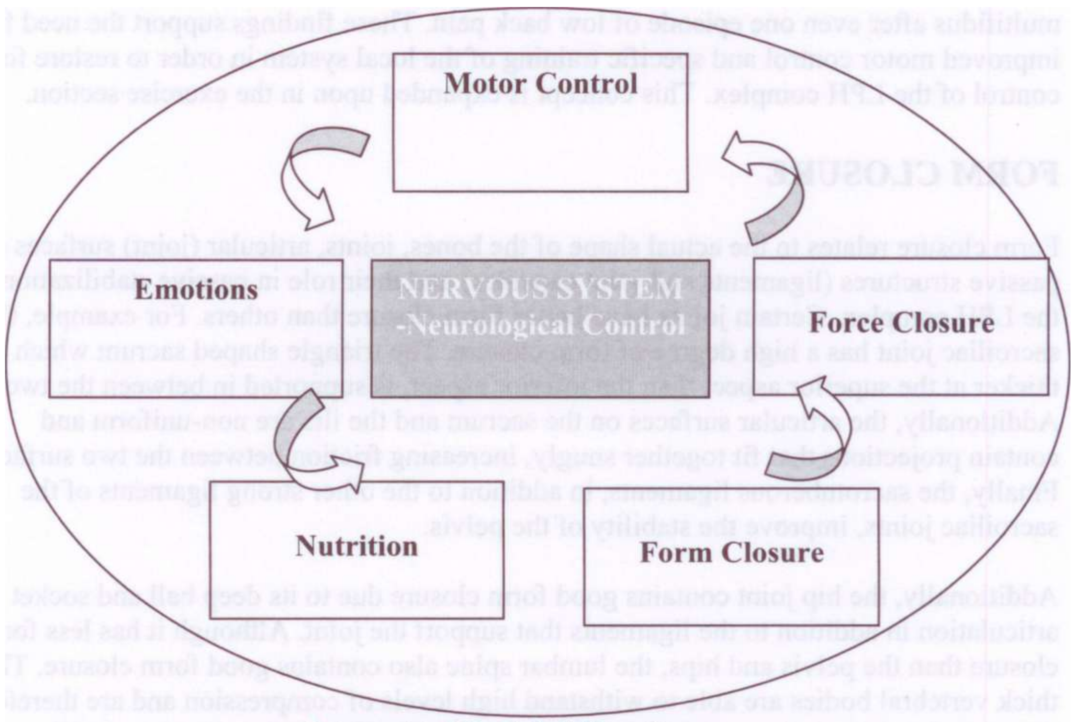
> ***Optimal function = effective load transfer***
>
> **Linda-Joy Lee**

Optimal function requires the ability to effectively transfer loads through the system. Ineffective load transfer often leads to biomechanical dysfunction manifesting as increased compressive loads on the spine and skeletal structures, an increase in tensile loads on the soft tissue structures, a resultant decrease in daily, occupational and/or athletic performance and, commonly, pain.

Decreased control of the core can be equated to driving a car with the wheels of the car not bolted on tightly. While the car will still operate, the performance of the vehicle will be severely limited, and breakdown is inevitable. So it is with the core. The importance of core stabilization cannot be overemphasized, as poor core function will **always** lead to dysfunction, and breakdown is inevitable.

When discussing dysfunction of the core, much attention has been given to the muscular system. When dealing with low back pain in particular, many rehabilitation and fitness professionals are quick to address the muscular component of the dysfunction. Typically, a weakness in the system is addressed with strengthening exercises, and myofascial tightness/restriction in the muscular system is addressed by soft tissue release techniques. Articular (joint) dysfunction is addressed by specific manipulation. While each component is effective at addressing specific dysfunction, often this approach falls short in achieving long-term relief from chronic pain and dysfunction.

The ability to perform activities of daily living such as walking, carrying children, loading groceries into a car or athletic events such as running, kicking a ball or performing an overhead pressing motion has to do with how efficient the neuromusculoskeletal system is at transferring loads through the body. The successful completion of tasks such as these requires a strong structural base, adequate muscle force controlling the base, the necessary neural input to control the system and the proper emotional and physiological components to support the system. The Integrated Model of Function, designed by Vleeming and Lee, describes how these different systems contribute to effectively transfer loads across the body. The five components of effective load transfer, form closure, force closure, motor control, emotions and nutrition, will be described below.



Integrated Model of Function

MOTOR CONTROL

Although one of the most important concepts of proper stabilization of the LPH complex, motor control is perhaps the most misunderstood components in the rehabilitation and training of the neuromusculoskeletal system. Most individuals in the training and rehabilitation field understand and implement the component of strength in the articular (joint) control of the kinetic chain. In fact, there are no shortages of courses, books and magazines addressing this aspect. However, it is important to note that strength alone is not necessarily the component that is lacking in individuals with musculoskeletal dysfunction. Motor control is an equally important factor in controlling forces through the kinetic chain and the lack of motor control will inevitably lead to dysfunction of the system. Until recently, the idea of adequate motor control was rarely addressed in the gym environment and, only slightly more frequently, in the rehabilitation arena.

So why the recent emphasis on motor control? Commonly, a timing delay occurs between the local and the global systems disrupting the load transfer capabilities of the system. Work by Hodges et.al. has demonstrated a timing delay in the transversus abdominus (TrA) in individuals with low back pain. Hodges demonstrated that in individuals with no low back pain, activation of the TrA preceded limb motion. However, in individuals with low back pain, limb motion preceded activation of the TrA. They also found that the TrA became direction-specific (as opposed to working through any direction of trunk or pelvic motion) and contractions became phasic in nature rather than the ideal, which is tonic. A later study performed by Hodges et. al., additionally demonstrated an anticipatory reaction of the diaphragm to limb motion. Hungerford has demonstrated atrophy of the

multifidus after even one episode of low back pain. These findings support the need for improved motor control and specific training of the local system in order to restore force control of the LPH complex. This concept is expanded upon in the exercise section.

FORM CLOSURE

Form closure relates to the actual shape of the bones, joints, articular (joint) surfaces and passive structures (ligaments and joint capsules) and their role in passive stabilization of the LPH complex. Certain joints have better form closure than others. For example, the sacroiliac joint has a high degree of form closure. The triangle shaped sacrum which is thicker at the superior aspect than the inferior aspect, is supported in between the two ilia. Additionally, the articular surfaces on the sacrum and the ilia are non-uniform and contain projections that fit together snugly, increasing friction between the two surfaces. Finally, the sacrotuberous ligaments, in addition to the other strong ligaments of the sacroiliac joints, improve the stability of the pelvis.

Additionally, the hip joint contains good form closure due to its deep ball and socket articulation in addition to the ligaments that support the joint. Although it has less form closure than the pelvis and hips, the lumbar spine also contains good form closure. The thick vertebral bodies are able to withstand high levels of compression and are therefore a strong and stable platform in which to move upon. The facet joints (made up of the inferior articulating process of the superior vertebrae and the superior articulating process of the inferior vertebrae) support approximately twenty percent of the body's weight. Due to the sagittal plane orientation of the facets, they are able to provide a moderate amount of stability against transverse plane (rotation) forces. The intervertebral discs, interspinous and intertransverse ligaments, anterior and posterior longitudinal ligaments and the iliolumbar ligament as well as the joint capsule contribute to the stability of the spine.

FORCE CLOSURE

Research has demonstrated that without musculofascial influence, the osseous-ligamentous skeleton would buckle under relatively small compressive forces. Therefore, adequate muscular input is required to optimize stability as well as mobility of the spine. Optimum function requires the appropriate amount of compression across all joint surfaces. Either over-compression or under-compression of articular structures will influence the effectiveness of the system in achieving optimum performance.

Recently, there has been a push to understand the integrated function of the nervous, muscular, and skeletal systems. Works by Bogduk, Hodges, Hides, Richardson, McGill, Meyers, Vleeming and Lee to name a few have begun to explain how the body functionally integrates these systems to provide both stability and motion in the body. The next section will take a traditional look at how muscles of the core act in isolation. A more integrated view will follow which will begin to explain the rational behind developing a more functional approach during rehabilitation and conditioning programs.

Muscular System of the Core

The muscles of the core have been functionally categorized by Bergmark, Comerford, Richardson et al as having either a local or a global function. The primary function of the local system is to provide intersegmental stability to the spine, pelvis or joint structure thereby reducing rotational and translational stresses to these regions while preventing potentially damaging increases (hypomobility) or decreases (hypermobility) in joint motion. The function of the global system is to provide gross stability to the spine and pelvis in addition to providing general motion of the body. A more complete comparison follows in Table 1.3.

Local system (stabilization)

- Deeper, smaller muscles
- Segmental control over 1-2 joint segments
- Control intersegmental motion-rotational, translatory and shear forces
- Anticipatory activity (feed forward mechanism)
- Non-direction specific
- Higher resistance to fatigue

- *Inhibition secondary to stress/trauma/fatigue (delayed activation)

Training guidelines

- Respond best to low loads and levels of effort
- Increased frequency with low duration

Global system (movement)

- Larger, more superficial muscles
- Span many joint segments
- Produce gross motion
- Produce high force movement/stabilization that is nonspecific
- Direction specific
- Rapid fatigability

- *Increased activity (hypertonicity or spasm) secondary to stress/ trauma/ fatigue

Training guidelines

- Respond best to higher loads and levels of effort
- Decreased frequency and duration

Comparison of the Local and Global Systems

The table below categorizes the muscles of the LPH core based on their function as part of either the local or global system. While they are categorized by function, it is important to realize that some of the muscles may function as part of both systems since some of the fibers belong to each of the categories. For example, the deep fibers of the lumbar erector spinae have been categorized as part of the local system while the superficial fibers of the same muscle are categorized as part of the global system.

Local system	Global system
Diaphragm	Rectus abdominus
Transversus abdominus	External and internal obliques
Pelvic floor	Superficial fibers of erector spinae
Multifidus	Lateral fibers of quadratus lumborum
Lower fibers of the internal obliques	Iliacus
Deep fibers of psoas	Superficial fibers of psoas
Deep fibers of erector spinae	Rectus femoris
Medial fibers of quadratus lumborum	Adductors
	Gluteals
	Hamstrings
	Piriformis

Table 1.4 Comparison of the Local and Global Muscles of the Lumbo-Pelvic-Hip Core

INTRODUCTION TO FUNCTIONAL ANATOMY

It has been said that form equal function. In support of this, nature is infinitely abundant with examples of this concept. A tree, for instance, has a vast root system under the ground that not only supports the trunk and limbs above the ground, it additionally provides an absorption reservoir for nutrients and water. The *form* of the root system allows the tree to *function* as a living entity that provides shade, home for other living creatures and oxygen to support life on earth. Similarly, the form of the muscular, skeletal and nervous systems enables the human being to function in an upright posture capable of accomplishing innumerous physical and intellectual tasks.

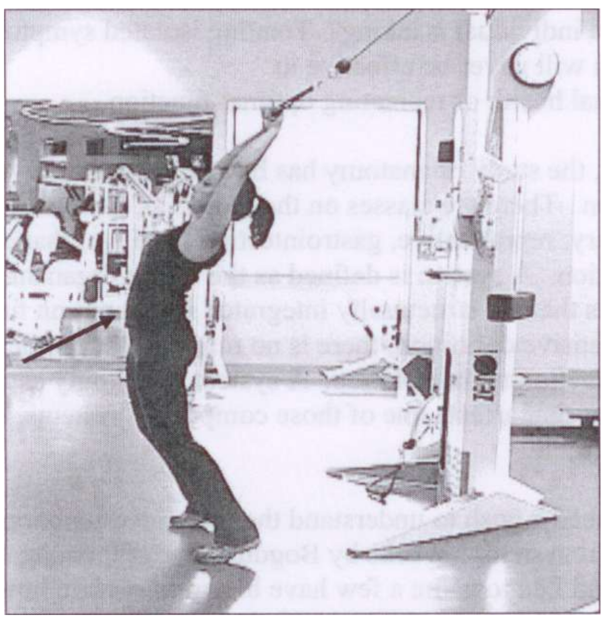
To aid in the understanding of the human form and function, scientists, researchers and philosophers across the centuries have attempted to explain each of the systems that constitutes the human body. Each individual, while brilliant in their own right, attempted to isolate each of the components of the human form with a lesser emphasis placed upon the whole being. This approach has perpetuated throughout the centuries as evidenced by the innumerous courses in anatomy, physiology, and neurology focused on just one region or system of the body. This concept has permeated into Western medicine where now there are almost as many medical specialists as there are conditions to treat. Is it only coincidental that many of the medications that are being prescribed are to counteract other medications the individual is taking? Treating isolated symptoms at the expense of the integrated system will never be effective in re-establishing optimal health or recreating optimal function.

As mentioned above, the study of anatomy has historically taken a very isolated approach to explaining function. There are classes on the muscular, skeletal, nervous, cardiovascular, urinary, reproductive, gastrointestinal, and lymphatic systems all focused on that particular region. A system is defined as the whole organism with all its related components and parts that are structurally integrated in a common function. While this appears to be an expansive definition, there is no reference or implication made to a system existing or functioning in isolation. A system exists only as a part of a larger system and something that affects one of those component systems, consequently affects the entire being.

Recently, there has been a push to understand the integrated function of the nervous, muscular, and skeletal systems. Works by Bogduk, Hodges, Hides, Richardson, McGill, Meyers, Vleeming and Lee to name a few have begun to explain how the body functionally integrates these systems to provide both stability and motion in the body. The next section will take a traditional look at how muscles of the core act in isolation. A more integrated view will follow which will begin to explain the rational behind developing a more functional approach during rehabilitation and exercise programs.

THE ANTERIOR ABDOMINAL WALL

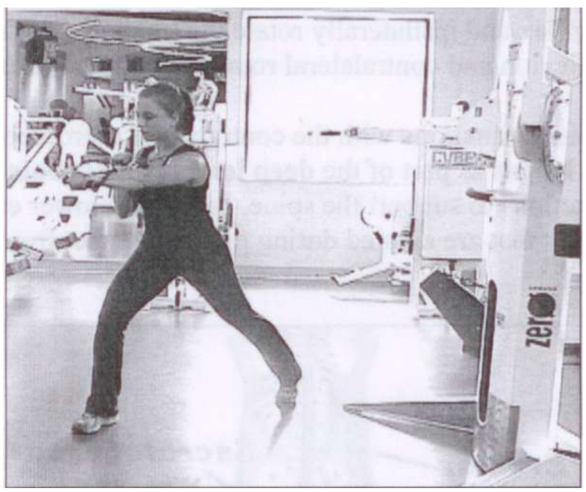
The anterior abdominal wall, including the rectus abdominus, external obliquus, internal obliquus and transversus abdominus have many important actions on the spine, thorax and pelvis. The rectus abdominus acts to flex the trunk and may assist lateral flexion of the trunk. The external obliques act to flex, lateral flex and contralaterally rotate the trunk. The internal obliques act to flex, lateral flex and ipsilaterally rotate the trunk. Synergistically, the rectus abdominus, external and internal obliques function to posteriorly rotate the pelvis. The integrated function of the rectus abdominus, external and internal obliques is to eccentrically decelerate extension of the trunk and the anterior rotation of the pelvis that occurs during functional tasks such as walking, running and throwing. Essentially, the abdominals maintain the trunk position over the pelvis during functional activities such as the gait cycle (see arrow in accompanying image).



Training the abdominal wall and flexor chain

Additionally, the ipsilateral external obliques along with the contralateral internal obliques and adductors, function as part of the **anterior oblique chain** during activities such as walking, running and throwing. See image 1 below.

Image 1. The anterior oblique chain


Training the anterior oblique chain

Through its attachments to the thoracolumbar fascia, the transversus abdominus has an important function in stabilization of the lumbar spine and sacroiliac joints. Unlike the rectus abdominus and oblique abdominals, the transversus abdominus through its attachments to the thoracolumbar fascia, provides intersegmental stabilization to the lumbar spine at each specific level. This is level of control can not be maintained by the rectus abdominus or obliques since they lack specific attachments to each vertebral level. Dysfunction in the transversus abdominus has been noted in those with low back pain and dominance of the global system.

Recall that the rectus abdominus, external and internal obliques and erector spinae have been classified as part of the global muscle system. Many individuals develop over-activation and over-dominance of the global system secondary to injury (creating

inhibition of the local system) and as a reaction to stress (fight or flight phenomena). Crunches are perhaps the most common exercise performed for the anterior abdominal wall. While effective at producing trunk flexion, crunch type exercises preferentially recruit the external obliques with little co-activation from the psoas thus there is the tendency to not only pull the lower ribs inferiorly but also acts to pull the pelvis posteriorly. This tends to create a strong flexion force through the trunk which is countered by a co-contraction of the lumbar erectors. Hyperextension exercises, commonly performed to train the erector spinae, additionally increase the compressive loads placed on the spine. The rectus abdominus, obliques and erector spinae each have attachments to the rib cage and pelvis. Therefore, the result of this co-contraction is an increase in the stiffness and rigidity of the trunk and spine. While an effective strategy in lifting heavy loads, the long term effect of this increased compression is the development of dysfunctional respiratory patterns (reciprocal breathing) and pelvic floor dysfunction (incontinence). This stabilization strategy may potentially inhibit the local system of the core and therefore increases the risk of injury to the discs, facet and other joint structures.

THE LUMBAR ERECTOR SPINAE

The lumbar erector spinae run the length of the spine from the pelvis to the skull. They act to extend, laterally flex and ipsilaterally rotate the trunk and spine while decelerating trunk flexion, lateral flexion and contralateral rotation of the same areas.

The lumbar erector spinae functions with the contralateral sacrotuberous ligament biceps femoris and peroneus longus as part of the **deep longitudinal chain** (image 2). The deep longitudinal chain functions to support the spine, pelvis and lower extremity in addition to transferring the forces that are created during ground contact from the leg through to the spine.

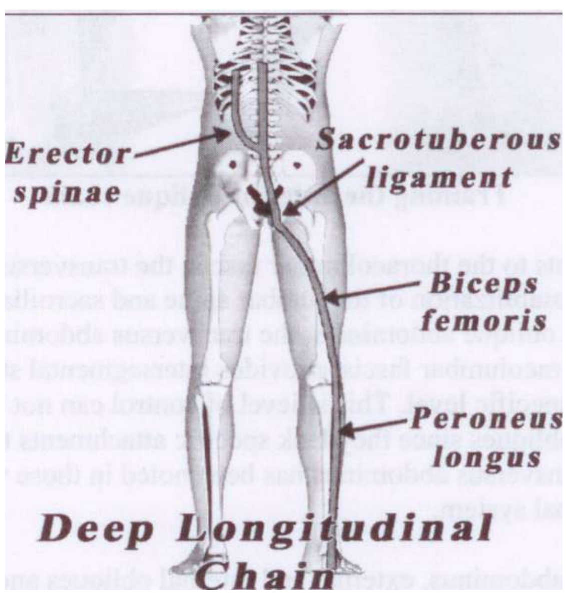


Image 2. The deep longitudinal chain

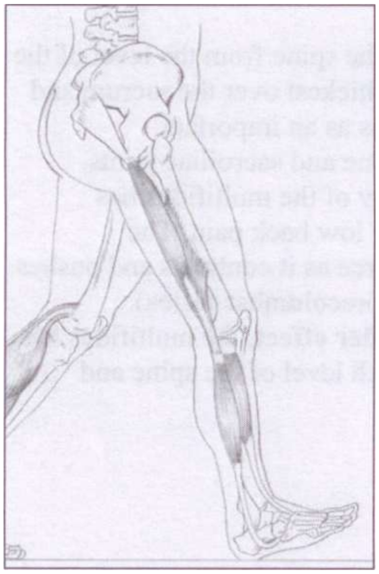
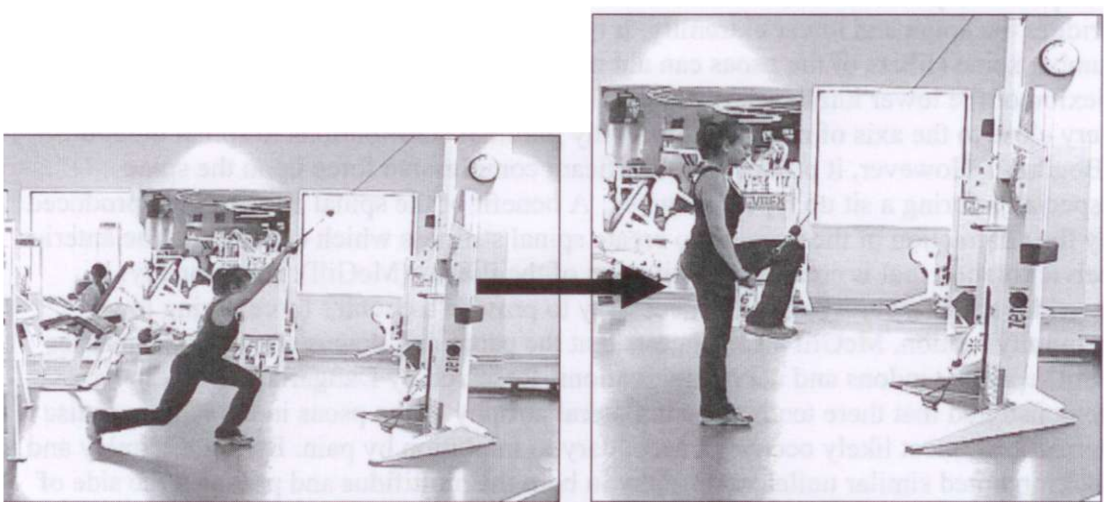


Image 2a. The deep longitudinal chain during the heel strike phase of the gait cycle.

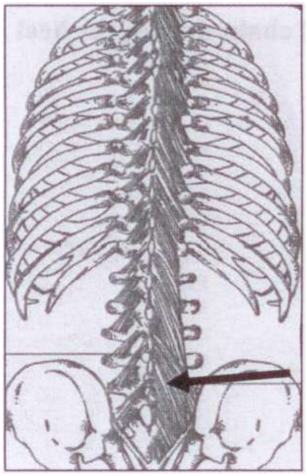


Training the deep longitudinal and lateral chains

QUADRATUS LUMBORUM

The quadratus lumborum produces lateral flexion of trunk and elevation of the pelvis with only minimal contributions to extension of the spine. Bogduk and others have indicated that the QL contains both superficial and deep fibers and is therefore classified as both a local and global muscle. McGill has demonstrated that the QL provides a lateral stabilization force that protects against buckling of the spine. It functions with the contralateral gluteus medius, tensor fascia latae and adductors as part of the lateral chain.

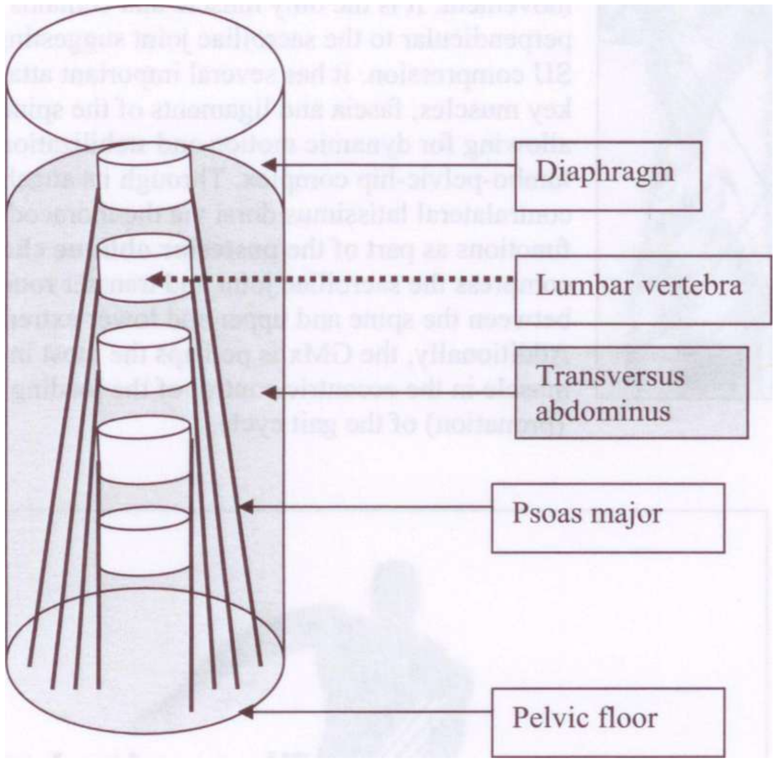
THE MULTIFIDUS



The multifidus runs the length of the spine from the level of the sacrum to the cervical spine. It is thickest over the sacrum and lower lumbar regions and functions as an important intersegmental stabilizer of the spine and sacroiliac joints. Research has indicated that atrophy of the multifidus has occurred after even one episode of low back pain. The multifidus exerts a stabilization force as it contracts and pushes against its fascial covering (the thoracolumbar fascia). Regarded as the **hydraulic amplifier effect,** the multifidus has a significant ability to stabilize each level of the spine and sacroiliac joints.

THE PSOAS

The psoas may be the most misunderstood muscle of the core. It is the only muscle that bridges the spine and lower extremity. It has classically been defined as a flexor of the lumbar spine (fibers of the psoas can aid in extension of the upper lumbar spine and flexion of the lower lumbar spine) and a flexor of the hip. Since the muscle is located very close to the axis of rotation, it has only minimal contributions to spinal motion (Bogduk). However, it produces a significant compressive force upon the spine especially during a sit up type maneuver. A benefit of the spinal compression produced by the contraction of the psoas is to create spinal stiffness which counteracts the anterior pelvic rotation that is created by activation of the iliacus (McGill). Additionally, it provides spinal stability which is necessary to provide a counter force during lower extremity motion. McGill also suggests that the psoas and iliacus are separate muscles with separate tendons and nerve innervations. Research by Dangaria and Naesh has demonstrated that there tends to be unilateral atrophy of the psoas in the region of disc herniations, most likely occurring secondary to inhibition by pain. Barker, Shamley and Jackson noted similar unilateral atrophy in both the multifidus and psoas on the side of low back pain. Research is currently being conducted by Comeford and others who suggest that the psoas acts to increase the stability or "stiffness" of the spine (see schematic below).

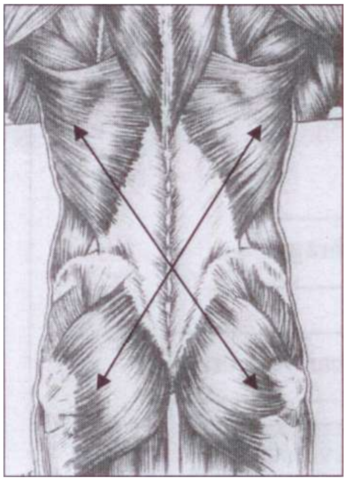


Schematic representing the canister effect of the lumbo-pelvic region

Historically throughout the literature, it has been thought of as a muscle that has created dysfunction of the spine and pelvis. It is often categorized as being overactive, resulting in a tight and shortened muscle. This creates an anterior rotation of the pelvis and subsequent increased lumbar lordosis (see Upper Crossed Syndrome). Anecdotally, the psoas tends to be lengthened and weak in many individuals. This occurs most commonly as a result of the seated posture and posterior pelvic tilting (taught and performed in many supine core exercises). This often creates a posterior pelvic rotation (tilt) and a decrease in the lumbar lordosis. This posture tends to inhibit the psoas and creates an increase in the activation of the other hip flexors especially the tensor fascia latae (TFL) and rectus femoris (RF). This puts the hip in a poor position since the psoas is important in maintaining an optimal axis of rotation by "drawing" the hip into the socket. The TFL and RF are located further from the axis of rotation and therefore tend to "jam" the hip

(drive the head of the femur anteriorly in the socket) during hip motion, especially during flexion. This is a common cause of the anterior "pinching" or impingement that occurs during hip flexion, adduction and/or internal rotation.

GLUTEALS



The gluteus maximus (GMx) is the largest muscle in the body suggesting it plays an important functional role in movement. It is the only muscle that contains fibers that are perpendicular to the sacroiliac joint suggesting its role in SIJ compression. It has several important attachments to key muscles, fascia and ligaments of the spine and pelvis allowing for dynamic motion and stabilization of the lumbo-pelvic-hip complex. Through its attachment to the contralateral latissimus dorsi via the thoracodorsal fascia, it functions as part of the **posterior oblique chain** serving to compress the sacroiliac joint and transfer rotational loads between the spine and upper and lower extremities. Additionally, the GMx is perhaps the most important muscle in the eccentric control of the loading phase (pronation) of the gait cycle.

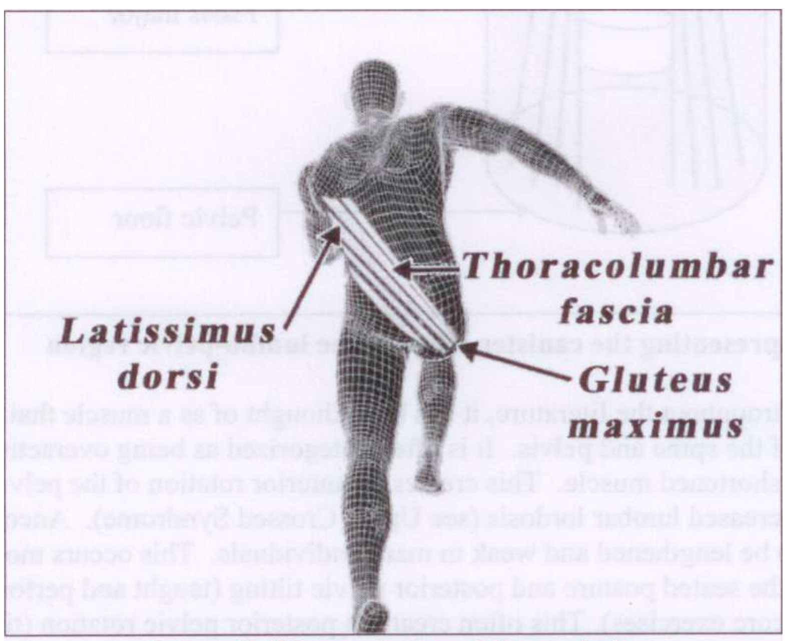


Image 3. The posterior oblique chain

The gluteus medius (GMd.), along with the ipsilateral adductors and tensor fascia latae and contralateral quadratus lumborum, function as part of the **lateral chain.** The lateral

sling provides coronal plane stabilization of the lumbo-pelvic-hip complex most notabaly during unilateral stance and the gait cycle.

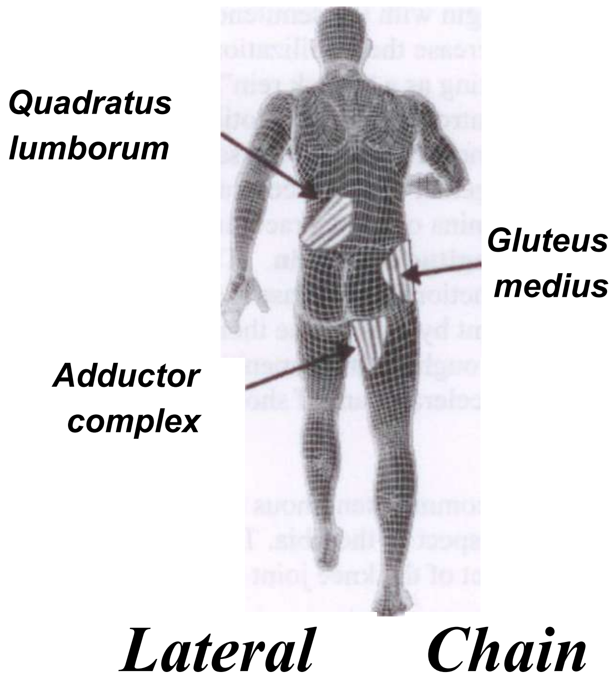
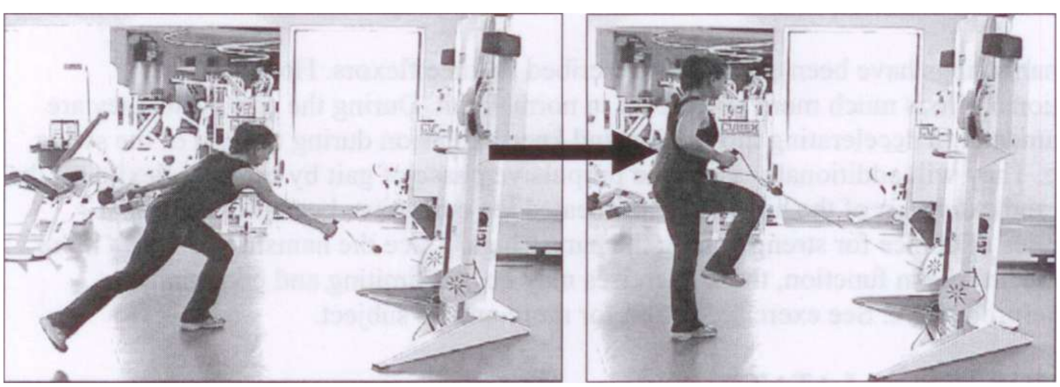


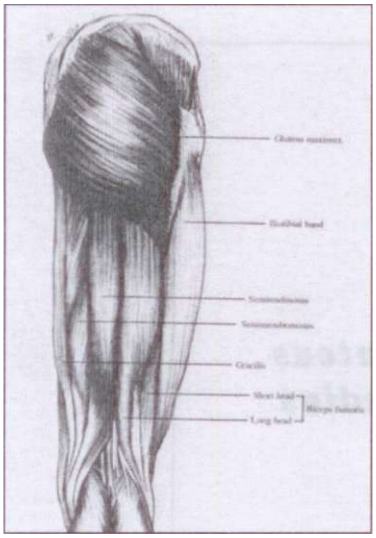
Image 4. The lateral chain

The gluteus minimus (GMn) functions with the gluteus medius in stabilization of the lumbo-pelvic-hip complex during unilateral stance. It may additionally function as a deep stabilizer, helping to maintain the optimal axis of rotation of the hip joint.



Training the posterior oblique and lateral chains

HAMSTRINGS



The biceps femoris (BF), originating from the supero-medial aspect of the ischial tuberosity, shares a common origin with the semitendinosus. This arrangement may increase the stabilization of the sacroiliac joint and by acting as a "check rein", potentially creates greater control over distal motion at the knee. Fascial attachments connect the BF to the sacrotuberous ligament which together with the contralateral erector spinae and deep lamina of the thoracolumbar fascia constitutes the **deep longitudinal chain.** The deep longitudinal chain functions to increase the stabilization of the sacroiliac joint by tensing the thoracolumbar fascia. The BF, through its attachment to the sacrotuberous ligament, decelerates and if short and tight, limits the degree of sacral nutation.

The semitendinosus (St) shares a common tendinous attachment with the sartorius and gracilis onto the anterior, medial aspect of the tibia. These muscles are the only muscles that directly cross the medial aspect of the knee joint and most likely provide medial stability to the knee.

The semimembranous has several fascial slips that run posterior and supports the posterior aspect the capsule of the knee (oblique popliteal ligament), laterally to cover the popliteus muscle (popliteal fascia), antero-medially to blend with the medial aspect of the joint capsule. Michaud relates the SM additionally has fascial attachments to the posterior horn of the medial meniscus and prevents impingement by pulling it posteriorly during knee flexion. Through its vast fascial attachments, the hamstrings most likely are an important stabilizer of the knee.

The hamstrings have been classically described as knee flexors. However, their functional role is much more significant in normal gait. During the gait cycle, they are instrumental in decelerating hip flexion and knee extension during the end of the swing phase. They will additionally assist the propulsive phase of gait by creating flexion of the knee and extension of the hip. Prone and seated leg curls have been the traditional exercises of choice for strengthening the hamstrings. Since the hamstrings have a more significant role in function, these exercises may be self limiting and potentially counterproductive. See exercise section for more on this subject.

TENSOR FASCIA LATAE

The tensor fascial latae (TFL) is important during functional movements such as squats, lunges and especially during unilateral stance. It functions as part of the lateral chain along with the ipsilateral gluteus medius/minimus and contralateral quadratus lumborum

to provide frontal plane stabilization of the lumbo-pelvic-hip complex. During the heel contact phase of the gait cycle, the TFL serves to counteract the posterior pull of the gluteus maximus which has a vast attachment to the posterior aspect of the 1TB. It additionally assists the iliopsoas during the swing phase in flexing and internally rotating the hip. The TFL will often become a dominant hip flexor when there is weakness of the iliopsoas complex. It will additionally become overactive as a frontal plane stabilizer when there is weakness or inhibition of the gluteus medius. Since it is also an internal rotator of the hip, if either one of the aforementioned functions become dominant, it can create increased internal rotation of the hip during single leg stance (increased pronation). As the hip internally rotates, there tends to be an increased lateral pull on the patella and fascia of the lateral thigh often leading to patellar tracking dysfunctions and iliotibial band syndromes. In certain cases, the TFL can become an extensor of the knee as the ITB migrates anteriorly on the thigh as is commonly seen in individuals with excessive external rotation of the hip.

PIRIFORMIS and DEEP ROTATORS OF THE HIP

The piriformis is important in deceleration of internal rotation of the hip during the loading phase of gait (pronation). It is an important stabilizer of the sacroiliac joint through its attachment to the anterior surface of the sacrum. Stiffness of the piriformis is often a cause of sacroiliac joint dysfunction in individuals that are utilizing a deep rotator stabilization strategy ("butt gripping" as described by Vleeming and Lee).

The deep rotators of the hip (DHR) include the piriformis, gemellus superior/inferior, obturator internus/externus, and quadratus femoris. Although external rotation of the hip is performed primarily by the piriformis and gluteus maximus, there is possibly contributory motion performed by the deep rotators of the hip. There is little research to date on the "true" function of the DHR however, their size and location suggests that they have a significant role as supporters of the pelvic floor and local stabilizers of the sacroiliac and hip joints. The literature confirms the obturator internus functions as part of the pelvic floor supporting the pelvic organs and providing stabilization of the lumbo-pelvic-hip complex. Over-activation of the deep rotators (butt-gripping as described by Vleeming and Lee) often occurs secondary to poor control by the local stabilization system, pregnancy, trauma, surgery and/or pain leading to increased compression through the hip joint. Approximately 170,000 hip replacements are performed each year suggesting the possible contribution of the DHR in generating compressive forces across the articular structures of the hip.

PELVIC FLOOR

The pelvic floor is collectively made up of the levator ani (which is comprised of the puborectalis, pubococcygeus and iliococcygeus) ischiococcygeus and obturator internus. To simplify the attachments, the pelvic floor essentially extends from the anterior surface of the ilium, sacrum and coccyx to insert into the pubic bone and pubic symphisis. The Pelvic Muscle Force Field (PMFF), as described by Janet Hulme, consists of the

obturator internus, pelvic diaphragm, urogenital diaphragm, external and anal sphincters and the hip adductors. She describes the PMFF as the rotator cuff of the pelvic floor. Collectively, the pelvic floor acts to produce counternutation of the sacrum thereby acting as a counter force against the pull of the multifidus. The iliococcygeus and isciococcygeus serve to compress the sacroiliac joint while the puborectalis acts to tighten the external anal sphincter. The pelvic floor additionally aids in the support of the pelvic organs. Weakness of the pelvic floor and/or over-activity of the global system are common causes of bladder incontinence often occurring secondary to pregnancy, abdominal or pelvic surgery or improper exercise selection (see section on global dominance).

The pelvic floor functions as part of the local stabilization system along with the diaphragm, transversus abdominus and multifidus providing control of the lumbo-pelvic-hip complex. The pelvic floor muscles share a common feed forward activation (anticipatory contraction) pattern as the other local core muscles. Co-contraction of the pelvic floor occurs with abdominal activation and likewise, activation of the pelvic floor creates co-contraction of the abdominals (Lee). This may be an anticipatory reaction to increased intra-abdominal pressure and provides protection against urinary leaking in addition to adding stabilization to the lumbo-pelvic-hip complex.

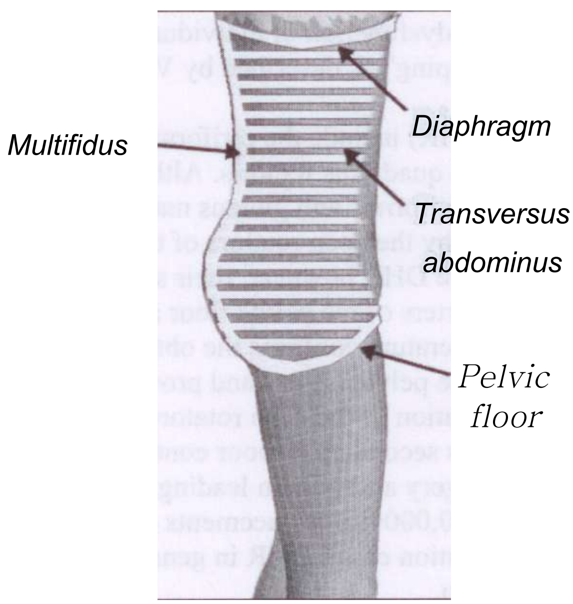


Image 5. Local system of the core

DIAPHRAGM

The diaphragm is the main muscle of respiration. With a wide attachment to the lumbar spine and rib cage, the diaphragm also functions to massage the organs as it moves during respiration. Research by Hodges and others has shown that the diaphragm functions as part of the local system in providing segmental stabilization to the spine. The diaphragm works in synergy with the transversus abdominus (TrA) in stabilizing the spine and rib cage during specific tasks. For example, there is a concentric contraction of the

diaphragm and an eccentric contraction during inspiration and during expiration, there is an eccentric contraction of the diaphragm and a concentric contraction of the TrA (Hodges). This enables proper respiration in conjunction with proper spinal stabilization. Along with the muscles of the pelvic floor, the diaphragm appears to stabilize the spine by providing a "hoop" like tension within the abdominal cavity. Stiffness or dysfunction in the thorax can lead to paradoxical breathing and therefore altered stabilization patterns of the trunk.

ADDUCTORS

The function of the adductor complex, including the pectineus, gracilis, adductor brevis (ABr), longus (ALg) and magnus (AMg), has been classically defined in anatomy texts as adductors of the hip joint. There seems to be little agreement between the texts as to whether they additionally assist internal or external rotation of the hip. However, a closer look at the size and complexity of this muscle suggests it has a much greater functional role than it has been previously assigned.

Giving credence to this point is the vast attachment points of several of the adductor muscles. For example, the proximal portion of the AMg serves as the origin of the vastus medialis and ALg has attachments via its aponeurosis to the AMg and ABr posteriorly and vastus medialis anteriorly suggesting its role in stabilization of the medial knee. The adductors also have a significant role in function. The adductor complex, along with the gluteus medius/minimus and the contralateral quadratus lumborum, make up the lateral chain. The lateral chain is responsible for frontal plane stabilization of the lumbo-pelvic-hip complex during unilateral stance such as during the gait cycle and during movements such as squats and lunges. The adductor complex additionally serves as part of the anterior oblique chain (ipsilateral internal oblique and adductor complex with the contralateral external oblique and hip external rotators) providing transverse plane stabilization during rotational movement patterns such as seen during the gait cycle and with throwing. During gait, the adductors show increased activity during the swing phase of gait indicating they may assist flexion and internal rotation of the hip. The adductor magnus seems to have constant activation throughout the gait cycle- the anterior fibers assist in hip flexion, the horizontal fibers assist in hip adduction (stance phase) and the posterior fibers aid in deceleration of hip extension during the terminal phase of gait.

RECTUS FEMORIS

The rectus femoris is a two joint hip flexor that additionally creates extension of the knee and acts to pull the pelvis anteriorly. Eccentrically, it decelerates extension of the hip, flexion of the knee and posterior tilting of the pelvis during loaded positions. It is often overstretched in individuals that demonstrate a posteriorly tilted pelvis and has been indicated in patellar tracking problems when it is overused secondary to psoas or vastii weakness.

NUTRITION

Very little attention has been given to the nutritional component and its relationship to stabilization of the LPH complex. While it is beyond the scope of this book to discuss all the correlative aspects of this topic, a few of the more pertinent ones will be discussed.

Viscero-somatic (an organ's ability to refer to and/or cause pain in nerve, bone or soft tissue structures) causes of pain can be seen in multiple examples in the body such as the gall bladder's referral pattern into the right shoulder, the prostate referring into the low back and heart problems manifesting as left sided jaw, chest and/or arm pain. While these are well known cause and effect relationships, few individuals, including doctors who specialize in gastro-intestinal disorders, recognize, let alone understand, or address the correlative effect of the diet on proper motor control of the abdominal wall.

While Eastern holistic healers and other natural health care professionals have long understood the importance of inflammatory reactions and disease processes in the body, it has only been a very recent phenomenon that Western medicine has even addressed this relationship. And what is their reaction to this idea of inflammation creating many of the disease processes afflicting the modern society, such cancer, heart disease and arthritis? Predictably, they create a drug that controls inflammation. This is not unlike throwing gas on a roaring fire in an attempt to put it out. So how does inflammation affect our motor control and ability to control the core? Following is a basic explanation of this phenomenon.

Many of the common foods the average American consumes at nearly every meal are poisons to our system. Processed foods, preservatives, carbonated beverages, artificial colors, flavorings and sweeteners, many grain products (including but not limited to wheat, oat, rice and rye) are allergens and therefore irritate the linings of the esophagus, stomach, small and large intestines. And it doesn't end just with the foods we eat. Most stimulants of the body including caffeine, nicotine, alcohol and prescription/non-prescription medications contribute to inflammatory reactions in the body. The body's reaction to any toxic substance is to create an inflammatory reaction to heal the damaged cell walls. This is often why certain food or food products will irritate many individuals and why the antacid market will never be short of business.

While beneficial in short doses, there is a downside to having chronic inflammation perpetuate our system. Left untreated, chronic inflammation leads to fibrotic changes in the linings of the affected tissue. This reduces the extensibility of the wall as well as mobility of the food or food particles that are traveling through the area. In his book *How to Eat, Move and Be Healthy,* Paul Chek suggests that inflammation and/or pain of the GI track causes a reflexive inhibition or weakening of the local stabilizers of the anterior abdominal wall. In particular, the transversus abdominus is extremely susceptible to this inhibition and therefore decreases the effectiveness of the body's muscular corset. Additional causes of this visceral-somatic inhibition include constipation, irritable bowel syndrome and Chrohn's disease.

Proper nutrition supports the GI tract in addition to the system as a whole. It provides the ground substances for tissue growth and repair while enhancing physiological and endocrinological processes in the body, which may have the benefit of elevating the mood, improving concentration and the mind-body connection necessary for proper core activation and motor control.

EMOTIONS

The psycho-somatic (a person's thoughts and emotions manifesting as nerve, bone or soft tissue pain) cause of pain and dysfunction is well known and documented in literature although not entirely understood. In fact, many doctors and therapists believe that the majority of low back and pelvic pain is entirely related to thoughts and emotions. While this may not be the entire story, there is no denying the dramatic effect that thoughts and emotions can have on the neuromusculoskeletal system. We have all experienced times when our energy has been low, or we've experienced mild depression and found it harder to hold our posture appropriately or to perform a certain exercise or sport activity that is usually easy to perform. The ability to perform these normal activities with greater of ease on good days is based upon our energy levels as well as our emotions, which affect and are affected by the nervous system. When we are in a good place (i.e. proper rest, good relationships, productive and positive activities), then our ability to perform complex motor tasks such as playing tennis or even less complex tasks such as performing activities of daily living painlessly is increased. However, nervous system fatigue or overload (secondary to a poor emotional state, too little sleep and/or stress) can have a dramatic effect on the ability or lack of ability to stabilize the LPH region. Similarly, individuals that have experienced severe trauma including physical, mental and especially sexual abuse, often have a decreased ability to exert the appropriate motor control to properly stabilize the LPH complex. These individuals will often demonstrate "guarded postures" including pulling the shoulders down and in, slumping through the trunk, posterior tilting of the pelvis and increased "gripping" through the deep hip rotators. While it is beyond the scope of this manual to discuss this subject in detail, it is important that therapists and trainers recognize the importance that emotions play in a person's ability to control their body and be able to adjust the rehabilitation and training protocols appropriately.

CONCLUSION

Several components add to the ability of the body to handle loads. Form closure, force closure, motor control, nutrition and emotions add to the stability and therefore the load transfer capabilities of the lumbo-pelvic-hip complex. The effectiveness of this approach will determine how successful an individual will be in performing activities of daily living, occupational and athletic events.

Section II

Insights to the Psoas Major

THE PSOAS MAJOR: INTRODUCTION AND FUNCTIONAL INTEGRATION

The psoas major (PMj) is one of the most interesting albeit misunderstood muscle of the lumbo-pelvic-hip region. Traditionally, we have been instructed as strength and conditioning specialists that the PMj is a muscle that is short and tight and typically requires stretching and/or release techniques. The purpose of this article is to provide a general overview and description of the basic biomechanics of the PMj and to introduce a functional continuum for rehabilitation and strengthening.

The PMj originates from the anterior surfaces of the vertebral bodies, transverse processes and intervertebral discs of vertebral levels T12-L5. It inserts along with the iliacus to the lesser trochanter of the femur. While it has been taught in anatomy classes to have a conjoined tendon with the iliacus, research by McGill suggests that the psoas and iliacus are separate muscles with separate tendons and nerve innervations.

The PMj has the distinction of being the only muscle that bridges the spine and lower extremities. While it has classically been defined as a flexor of the lumbar spine (it has been suggested that the fibers of the psoas can aid in extension of the upper lumbar spine and flexion of the lower lumbar spine), it has only minimal contributions to spinal motion due to the fact that it is located in such close proximity to the axis of rotation (McGill and Bogduk). However, it produces a significant compressive force upon the lumbar spine especially during a sit up type maneuver. One benefit of the spinal compression produced by the contraction of the psoas is to create spinal stiffness which counteracts the anterior pelvic rotation that is created by activation of the iliacus (McGill). Additionally, it provides spinal stability which is necessary to provide a counter force during lower extremity motion. The main action of the PMj appears to be flexion of the hip as it demonstrates peak activity during hip flexion on EMG analysis and only minimal action during spinal motion (McGill).

Similar to many of the spinal muscles, the PMj seems to contain both deep and superficial fibers. In fact, some have classified the deep fibers of the PMj as part of the local or deep stabilization system of the lumbo-pelvic-hip complex (Bergmark, Comerford, Hodges and Lee). The local muscles are the muscles most responsible for direct control of joint motion. They are typically the muscles that cross only one joint and are located in direct approximation to the axis of joint rotation. Two important points of these muscles are: 1. They are anticipatory and activate prior to limb motion. 2. They tend to become weakened and inhibited by pain, fatigue and deconditioning (inactivity).

Research by Dangaria and Naesh has demonstrated that there tends to be unilateral atrophy of the psoas in the region of disc herniations, most likely occurring secondary to inhibition by pain. Barker, Shamley and Jackson noted similar unilateral atrophy in both the multifidus and psoas on the side of low back pain. Research is currently being conducted by Comerford and others who suggest that the psoas acts to increase the stability or "stiffness" of the spine. The analogy created by Comerford is that the thoraco-lumbar region is a canister and the psoas acts to increase the stability within the canister (see figure 1 below).

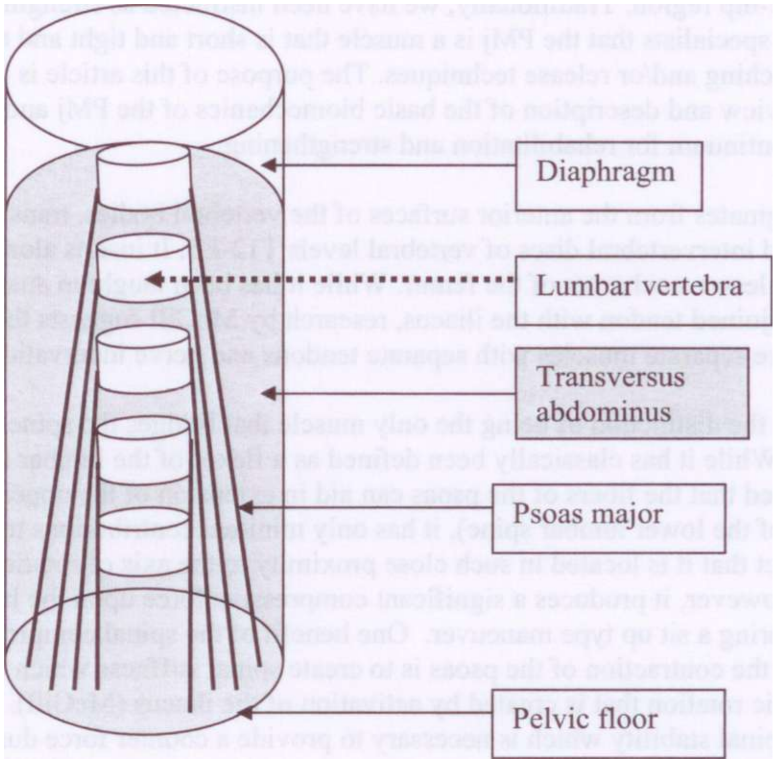


Figure I. Schematic representing the canister effect of the lumbo-pelvic region

Throughout the literature, the PMj has been thought of as a muscle that has created dysfunction of the spine and pelvis. It is often categorized as being overactive, resulting in a tight and shortened muscle. This creates an anterior rotation of the pelvis and subsequent increased lumbar lordosis (lower crossed syndrome as has been defined by Janda).

Postural Alterations	Shortened/overactive muscles	Weakened/inhibited muscles
Increased lumbar lordosis	Lumbar erector spinae	Abdominals
Anterior pelvic tilt	Hip flexors -Iliopsoas -Rectus femoris -Tensor fascia latae Lumbar erector spinae	Gluteals Hamstrings Abdominals

Table I. Lower Crossed Syndrome

Clinically, we have found that the PMj is a muscle that tends to be lengthened and weak in many individuals. This occurs primarily for two reasons: 1. Poor core stabilization patterns leading to over-activation of the deep external hip rotators ("butt gripping"). 2. Secondary to seated postures (see images below) and postures encouraging posterior pelvic tilting (taught and performed in many supine core exercises). Both of these situations lead to a posterior pelvic tilt and a decrease in the lumbar lordosis. This posture tends to inhibit the PMj and creates an increase in the activation of the other hip flexors mainly the tensor fascia latae (TFL) and rectus femoris (RF). This places the hip in a poor position since the PMj is important in maintaining an optimal axis of rotation by "drawing" the hip into the socket. The TFL and RF are located further from the axis of rotation and therefore tend to "jam" the hip (drive the head of the femur anteriorly in the socket) during hip motion, especially during flexion. This position is further exacerbated by an over-activation or "gripping" of the deep external rotators of the hip which also tend to drive the hip forward into the socket. These are common causes of anterior "pinching" or impingement that occurs during hip flexion, adduction and/or internal rotation performed in a supine position.

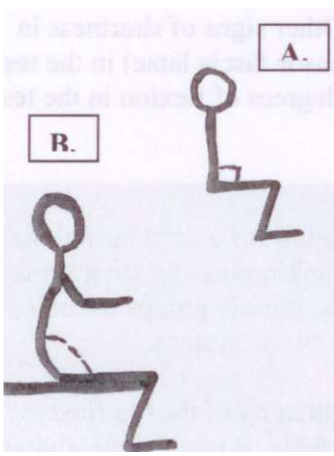


Figure 2. Effects of seated postures on the psoas
Many readers have been taught that seated postures create a shortening in the psoas (Janda's Lower Crossed Syndrome). If the individual is sitting in an upright posture where the hip is at a 90 degree angle to the trunk and pelvis, this would be true (image A). However, this is not the case for most individuals. With typical sitting postures, the pelvis tilts posteriorly and the lumbar spine goes into obligatory flexion. This posture lengthens the psoas at its origin and often there is a reciprocal extension at the thoraco-lumbar junction or mid thoracic spine (image B). Therefore, it is imperative to properly assess all clients before instituting a stretching program for the psoas.

Exercise Prescritption

As previously noted the PMj is a muscle that tends to be weak and inhibited in many individuals. It is important to assess for a length weakness before any assumptions are made regarding PMj function. The traditional length test for the PMj is the modified Thomas test. The client begins sitting at the edge of a treatment table and pulls one leg into their chest (maximal flexion of the hip and knee). The examiner helps the client lie back onto the table with the opposite leg extended off the table. The examiner helps the client hold the leg into their chest during the test in order to stabilize the lumbar spine. If the thigh does not lie in a position parallel to the table, the PMj is considered to be short and tight. If the thigh lies parallel to the level of the table, the PMj is considered to be of normal length. If the thigh lies below the level of the table, the PMj is lengthened or over-stretched. Often times, an individual presents with an apparent anterior pelvic rotation (tilt) but the PMj appears to be of normal length or even lengthened during the Thomas test. Typically, the PMj is lengthened and there is synergist dominance of the synergistic hip flexors, mainly the tensor fascia latae and rectus femoris (see side note below). Assess for this by positioning the pelvis in a neutral position on the table and reassessing the position of the thigh. If the thigh does not lie parallel to the level of the table, there is shortening of the tensor fascia latae and/or rectus femoris. Other signs of shortness in these muscles are abduction of the thigh (shortness of the tensor fascia latae) in the test position and the knee position can not be maintained at 90 degrees of flexion in the test position (shortness of the rectus femoris.

Sherrington's law of reciprocal inhibition states the antagonist of a tight muscle will be inhibited through impaired reciprocal inhibition. Sustained inhibition of a muscle may result in **synergist dominance,** a process where the synergist muscle groups become overactive in an effort to maintain the normal biomechanics of the system.

An example of this principle occurs with shortening and tightening of the hip flexors. Shortness and tightness in the tensor fascia latae and rectus femoris inhibits the gluteus maximus which contributes to an anterior tilting of the pelvis. This positioning of the pelvis lengthens the posterior fibers of gluteus medius and places it in a less than optimal position in stabilizing frontal plane motion of the pelvis. The overstretching of the gluteus medius leads to a stretch weakness in the posterior fibers. This creates a situation in which additional stress is placed on the tensor fascia latae to aid in the stabilization of the pelvis. If this position is chronically maintained, the tensor fascia latae becomes the dominant frontal plane stabilizer of the pelvis and perpetuates the anterior tilt of the pelvis. Additionally, the tensor fascia latae will often compensate for a weakened iliacus and become a prime mover in hip flexion. Overactivity in the tensor fascia latae is a common cause of hip dysfunction, low back pain and iliotibial band syndromes.

Table II. Reciprocal Inhibition

Traditional muscles testing for the PMj has the client in an upright seated position (or supine with the hip flexed and slightly externally rotated) with the legs hanging off the

edge of the bench. The client flexes the hip so the thigh is off the table and the examiner applies resistance by trying to push the thigh back to the table. While this position will test the strength of the PMj, the tensor fascia latae, rectus femoris and adductors tend to be strong enough that they can conceal a weakness in the PMj. Clinically we have discovered a more accurate way to test the PMj. The client lies supine on the exam table with the hip flexed and abducted to approximately 30 degrees and slight externally rotated. The knee should remain straight. The examiner places one hand on the client's contralateral anterior superior iliac spine in order to stabilize the pelvis. A steady and increasing downward pressure is applied to the elevated leg just proximal to or just distal to the knee. The client should be able to maintain the leg in the test position under moderate resistance. If the leg easily gives in to the resistance, weakness is suspected in the PMj. Another clinical sign of a weak PMj is the presence of a long leg viewed in the supine lying position (one function of the PMj is to maintain the integrity of the femoral head in the acetabulum). Ensure that the pelvis in neutral alignment prior to making this assessment as an intra-pelvic torsion can create a functional long leg.

Strengthening of the PMj can be difficult in the presence of increased tonicity in the tensor fasica latae, rectus femoris and adductors or restriction in the posterior hip capsule. One function of the PMj is to maintain an optimal axis of rotation of the hip joint. In other words, the PMj maintains the alignment of the femoral head in the acetabulum. Therefore, any situation that alters the femoral head position will affect the function of the hip and therefore need to be addressed prior to PMj strengthening. Visualization and imagery techniques can be used to reduce activation of the tensor fascia latae, rectus femoris and adductors. Muscle energy and contract/relax techniques are extremely effective in releasing restrictions in the posterior hip capsule.

Psoas strengthening begins with teaching proper local stabilization activation. Recall that the deep fibers of PMj are likely part of the local system and therefore act in feedforward manner (have an anticipatory action to movement). Basic core activation includes isolation of the local system. The local system is vital to the stabilization of the core and is composed of muscles that form a muscular "girdle" around the spine, pelvis and hips. These muscles co-contract prior to motion to provide joint stabilization and provide a stable platform in which to create motion. The local system consists of the diaphragm (DG) which forms the roof, the pelvic floor (PF) which forms the floor, the transverse abdominus (TrA) forming the anterior and lateral walls and the multifidus (MU) which makes up the posterior wall. Recall that the deeper fibers of the PMj are likely part of the local muscle stabilization system.

- Begins with a neutral spine and pelvic position.
- Take a deep breath in through the nose while focusing on costal expansion (expansion through the rib cage).
- Breathe out through the mouth while focusing on relaxing through the rib cage. During the exhalation, instruct the client to gently "draw in" the TrA and "pull up" the PF. (It should feel as if there is a slight tensioning in the lower abdominal region and that there is a lifting of the pelvic floor, similar to performing a Kegel maneuver).

On visual inspection, it should appear as if the navel were being pulled straight back towards the spine (white arrow) with no abdominal bulging or bracing which indicates over-activity of the oblique abdominals. To connect the MU, "imagine" a wire going through the abdominal cavity connecting the TrA and PF with the MU which run directly along the spine connecting vertebrae to vertebrae. The spine and pelvis should remain neutral and not move during the activation (black arrow). A tensioning should be noted around the pelvis, abdomen and low back region and proper diaphragmatic breathing should be able to be maintained effortlessly throughout the movement. The rib cage should be mobile and not feel stiff if moved (wiggled) side to side. There should be no activity in the obliques during the basic activation.

To integrate PMj activation, imagine a line (or wire) connecting from the spine to the hip. Visualize pulling from deep inside and allow the hip to sink back into the socket as the hip is brought into flexion. Maintain this connection especially during eccentric loading (as the leg is extended).

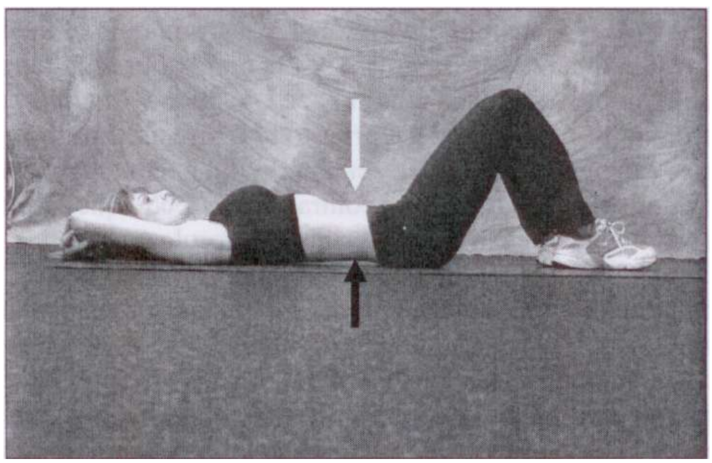


Figure 3. Basic Core Activation

*Note that the arms are held overhead in the following pictures for demonstration of neutral spine position only. Raising the arms overhead tenses the thoracolumbar fascia via the latissimus dorsi and increases the anterior tilt of the pelvis. Therefore, keep the arms by the side during the basic movement progressions.

The following progressions are adapted and modified from Shirley Sahrmann's lower abdominal progression (figures 4-8). It is adapted according to the client's ability to perform them while following the following guidelines.

- Ensure proper core activation during each version and progress at the rate at which the core remains activated and no motion occurs in the pelvis or spine.
- Monitor for the following signs of breakdown in control of the core: rotation of the pelvis or spine as the leg is lifted and moved, arching of the back or ribcage (increased lumbar or thoracic erector spinae activation) and abdominal "bulging" (increased diameter of the abdominal region).

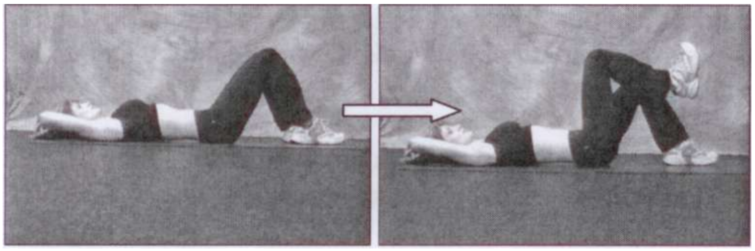


Figure 4. Level 1

Figure 5. Level II

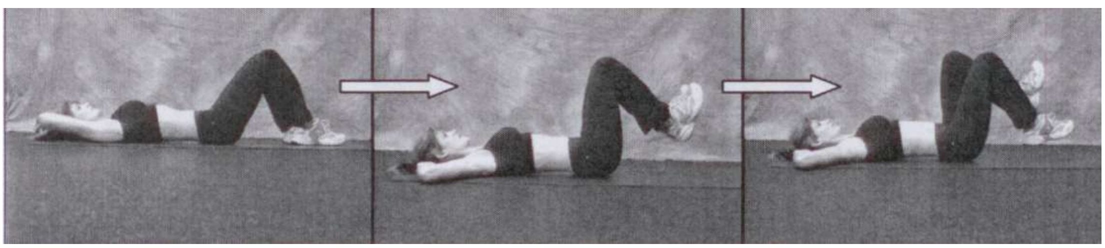


Figure 6. Level III

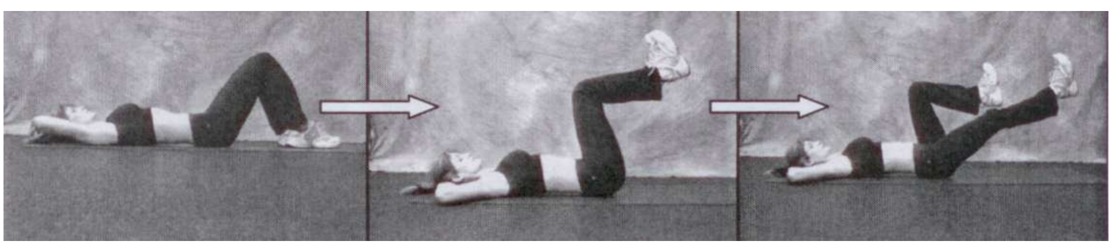


Figure 7. Level IV

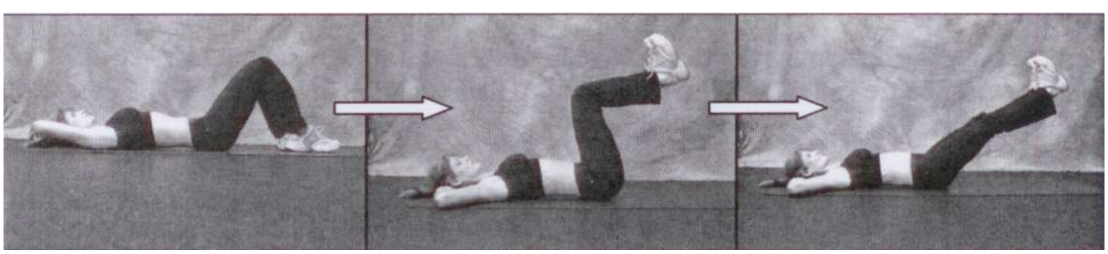


Figure 8. Level V

Once the basic core activation series can be performed for up to 50 repetitions per leg at level III or higher, progress to either slide board or ball tucks to functionally integrate the PMj into general movement patterns.

The slide board requires excellent core control during motions of either the lower or upper extremities and is a great tool for training the entire kinetic chain.

- Begin the progression in the plank position and perform alternating hip flexion.
- This can be performed utilizing a slow tempo (one leg in, one leg out) or a continuous faster paced tempo replicating more of a running cadence (figure 9).
- The pike slide follows the single leg version as this version requires tremendous core strength and stability (figure 10).
- Be sure to maintain core activation throughout the movement and neutral spine throughout the movement.

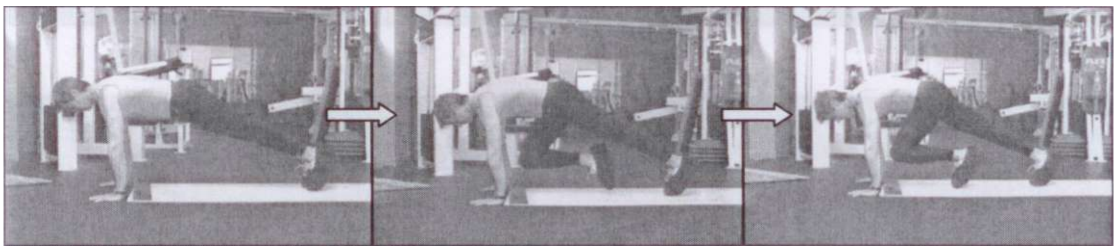


Figure 9. Alternating slide board hip flexion

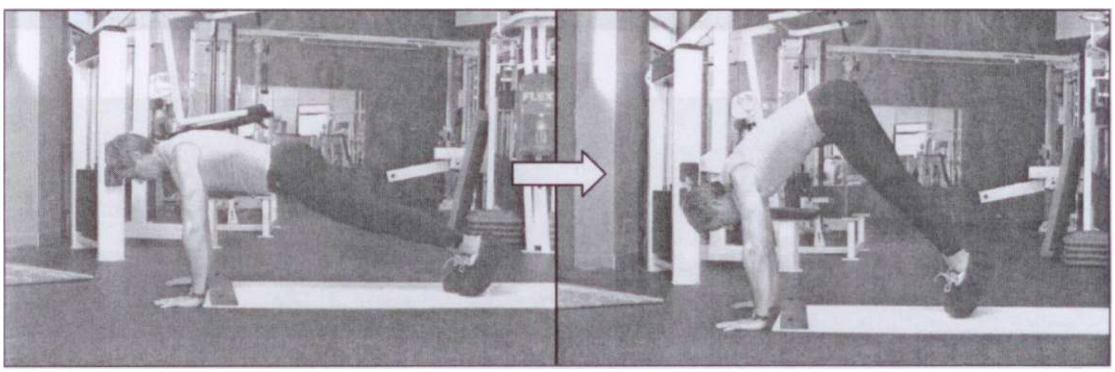


Figure 10. Slide board pike

Prone hip tucks are a great way to improve hip function common, albeit high-level, exercise that focuses on the stabilization system from the shoulders through the core (figure 11).

- Begin by maintaining an isometric hold of the neutral spine position with the ball at the hips, at the knees, at the ankles and finally with the toes on the ball.
- Progress to prone hip tucks by pulling the knees towards the chest.
- Maintain a neutral spine and pelvic position throughout the hip flexion motion.

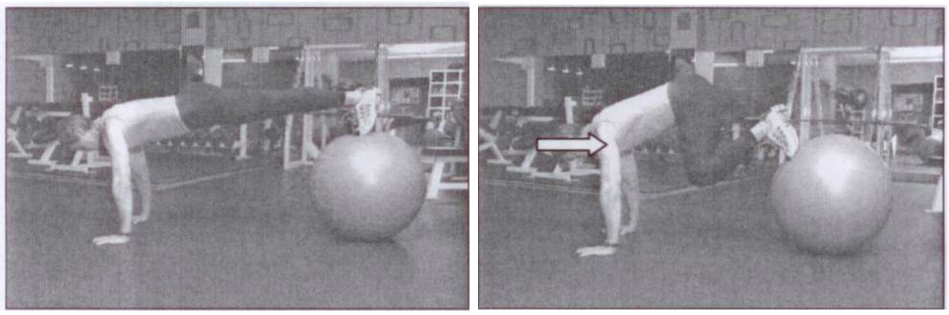


Figure 11. Prone Hip Tucks

Adding a rotation component by rotating the trunk as the knees are pulled in targets the trunk rotators while increasing stabilization demands to the shoulder girdle (figure 12). As with the above versions, refrain from these movements in those with low back pain and/or instability.

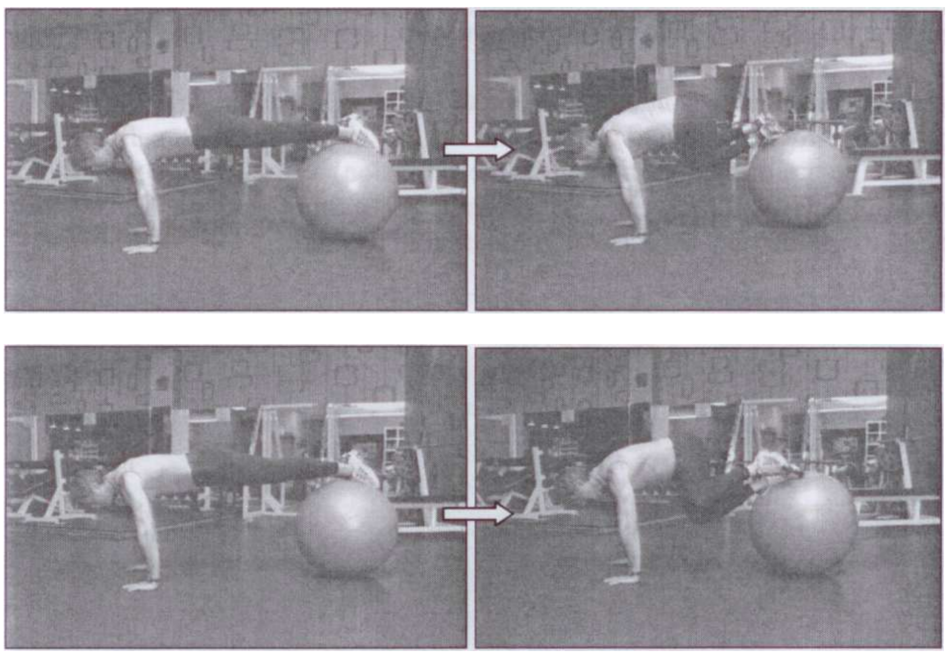


Figure 12. Prone Hip Tucks with Rotation

As the PMj improves in strength and endurance, progress to the straight arm cable pull down to unilateral stance (figure 13). This is an excellent move which not only improves functional strength of the PMj (spinal stability during hip flexion) but additionally improves coordination of the posterior oblique, deep longitudinal and lateral chains. Begin in a split stance with one leg on a step and the arm straight grasping a cable. Step up onto the step into a unilateral stance (triple extension). The contralateral hip should simultaneously be flexing (at the hip, knee and ankle) as the arm is pulled down to the side. Maintain a neutral spine and core activation throughout the movement.

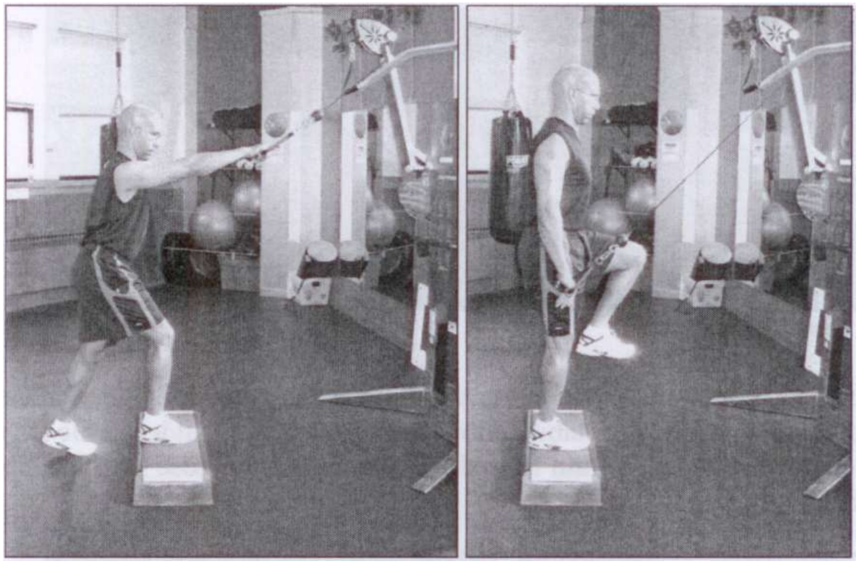


Figure 13. Straight arm cable pulldowns to unilateral stance

The final progression includes dynamic hip flexion to unilateral stance with cable resistance (figure 14). Attach a cable to one hip and assume a split stance (see image below). Drive from the hip of the forward leg (triple extension) as the rear hip is flexed at the hip, knee and ankle. Hold for a second and return to the starting position. Make sure the drive is up and the spine remains neutral throughout the pattern.

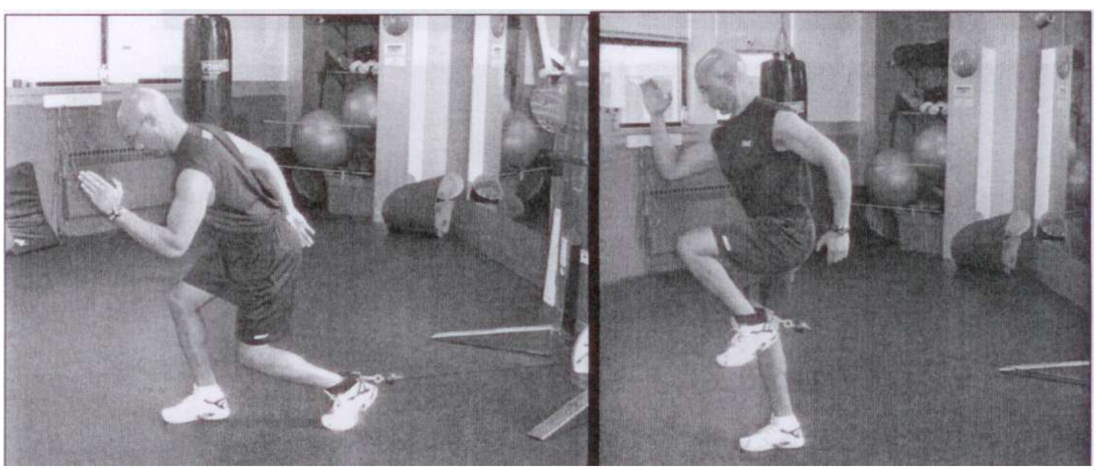


Figure 14. Unilateral stance to single leg hip flexion with cable attachment

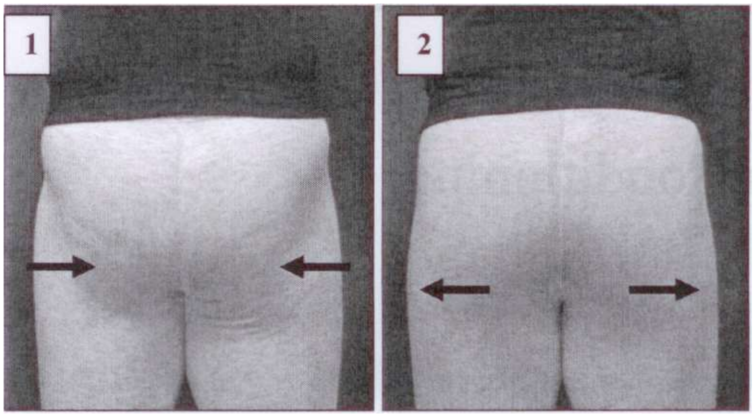
Conclusion

As described in this article, the PMj is an often misunderstood muscle that directly impacts the function of the lumbar spine, pelvis and hip complex. It is important to properly assess for proper length and/or weaknesses prior to initiating a treatment or training program. With proper integration and sequencing, increases in PMj function lead to improved core and hip performance and decreases the likelihood of low back and/or hip dysfunction.

Section III

Functional Hip Conditioning

Common Hip Dysfunction



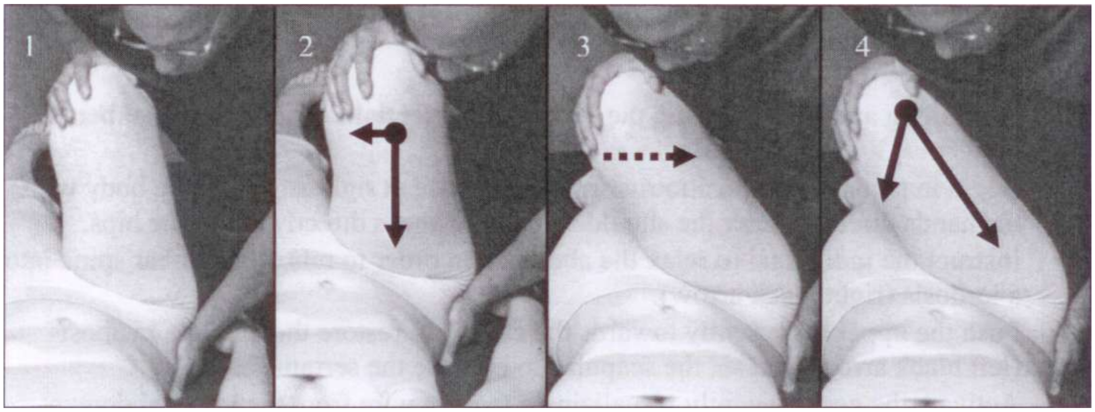
The individual in the accompanying photos presented with pain in the hips and sacroiliac joints. Notice the indentation or hollowing (arrows) in the lateral hip region created by over-activation of the deep external rotators of the hip (image 1). Palpation over the lateral hip region will reveal an indentation or hollowing. With this "gripping" pattern, the head of the femur will be pushed forward in the socket. The head of the femur can be palpated by placing the hands just medial to the anterior superior iliac spine (ASIS). Typically, an increased tone or "fullness" will be noted in the tensor fascia latae (just lateral to the ASIS).

By cueing the individual to relax the hips and spread the sit bones (arrows), there is a change in the tone in the posterior hip region (image 2). Palpation over the anterior hip region will reveal the head of the femur has been centered in the socket secondary to the relaxation of the posterior hip muscles.

While the previous technique is extremely effective for releasing hip gripping patterns, some individuals require more specific techniques for decreasing activation of the deep hip rotators. See next section for releasing posterior hip restrictions.

Re-seating the Femoral Head

The following technique is extremely effective for improving hip mobility secondary to a posterior hip capsule restriction and releasing overactive muscular structures around the hip including the deep external rotators (gemelli and obturators) and the tensor fascia latae. Additionally, it improves the position of the hip in the socket (centers the femoral head in the socket).



Begin with the client in a supine position with the examiner standing on the affected side. The examiner places their superior hand around the lateral aspect of the iliac crest with the fingers monitoring the posterior aspect of the hip and the inferior hand cupped around the clients knee (1). Beginning with a gentle compression, the examiner moves the hip into flexion, adduction and internal rotation until a tautness (ability to easily move the joint stops) is felt (2). The examiner holds resistance at that point and the client pushes (with approximately 25% of their strength) into the examiners resistance for approximately 5 seconds (3). As the client relaxes, the examiner gives the cue to "relax the hip" or to "let the hip sink gently back into the socket" as they move the hip to the next barrier or the point at which the joint can not be easily moved (4). This cycle is repeated 3-5 times or until no further motion at the hip joint is possible. Additionally, with the superior hand the examiner can palpate a taut area in the posterior hip region and instruct the individual to relax underneath their fingers by using the cue "allow the muscles to melt under my fingers."

Follow up this technique with quadraped weight shifts (see below).

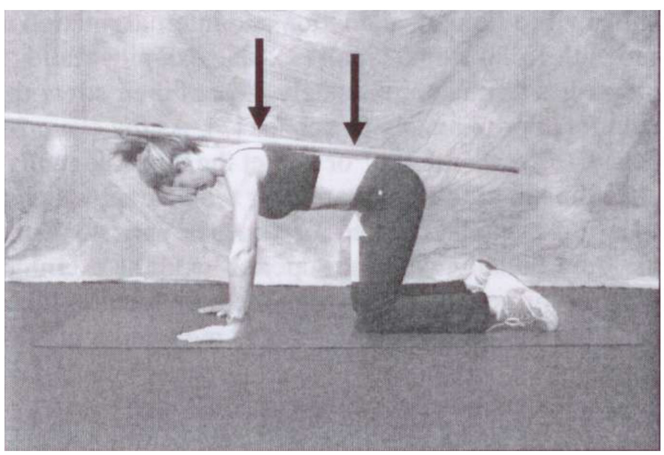
Modified and adapted from specific techniques and cues as taught by Linda Joy Lee.

Quadraped Weight Shifts

As discussed earlier, a common cause of hip restriction is stiffness or tightness in the posterior hip capsule. Stretching of the posterior hip joint structures is rarely effective when there is a restriction in the joint capsule. Quadraped weight shifts are an excellent way to mobilize the hip joint while teaching the individual neutral spine posture, proper core activation and motor control (relaxation) of the deep hip rotators. Additionally, it aids in the teaching of neutral scapulae loading in a low load position. It is an excellent exercise to give individuals who have had their hips released from contracted muscular contractions or capsular restrictions.

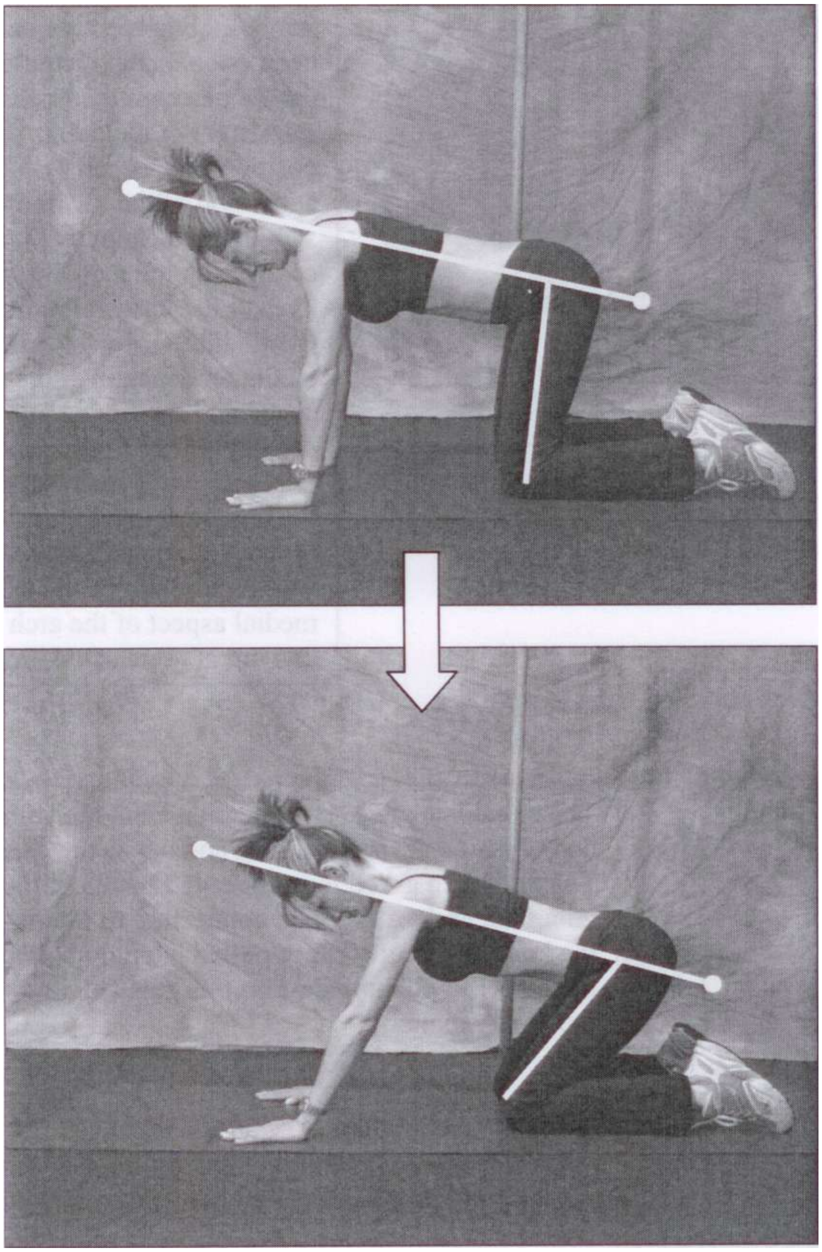
Proper positioning and cueing during the exercise is essential to obtain maximal benefits.

- Begin in a quadraped position- arms and hips are at right angles to the body with the hands directly under the shoulders and the knees directly under the hips.
- Instruct the individual to relax the abdomen in order to relax the lumbar spine into a lordosis (right black arrow).
- Push the upper back gently towards the ceiling to restore the thoracic kyphosis (left black arrow) and set the scapulae to activate the serratus anterior.
- Activate the core by gently visualizing a tension wire from the lower abdomen (white arrow) to the low back (or any unstable segment in the spine).
- Visualize a wire attached to the top of the head and one attached to the tailbone- imagine the wire on the top of the head and the one on the tailbone being pulled in opposite directions, gently elongating the spine



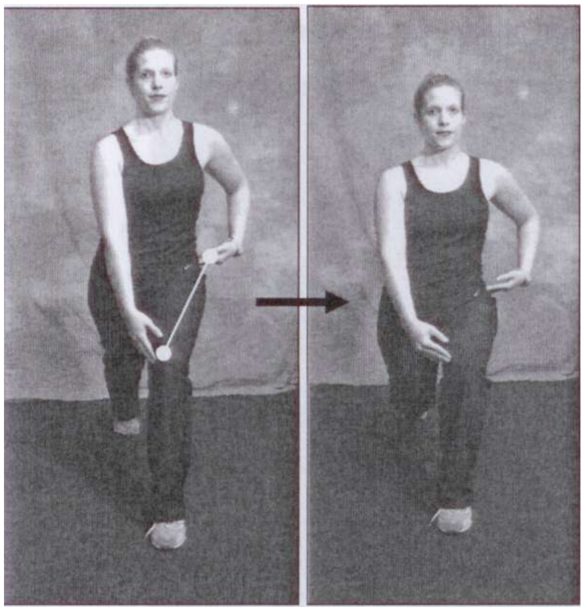
- Push through the arms and glide back through the hips- be sure to monitor and cue relaxation through the posterior hips and maintenance of neutral spine
- Continue sliding back as long as the spine remains neutral and there are no deviations through the pelvis and/or spine (lateral shifts of the pelvis or spine or flexion of the lumbar spine).
- Return to the starting position- as the individual relaxes and "lets go" through the hips, increase the range of motion.

- Visual cues such as "spreading through sit bones (ischial tuberosities)", "relax through the back of the hips" and "let the hip sink back into the socket" are effective ways to enhance mobilization of the joint capsule.



Quadraped weight shifts- Monitor that the individual moves only within the hip flexion range of motion. Be sure to assess for neutral spine and core activation throughout the movement.

Hip Stabilization Techniques


Gluteus medius activation

Once the hip position has been re-established (see above techniques) and lumbo-pelvic-hip core activation has been established, increased attention can be place on the functional stabilizers of the pelvis in the upright position. Focus can be placed on activation of the lower extremity stabilization chain by visualizing a wire connecting the medial aspect of the knee to the lateral portion of the hip (white line) or by the client applying tactile feedback over the ipsilateral VMO and the GMed. For clients demonstrating a pronation syndrome (adduction and internal rotation of the hip and knee in addition to collapse of the medial longitudinal arch of the foot), a line can be visualized from the medial aspect of the arch to the ipsilateral gluteus medius.


Lower extremity stabilization technique

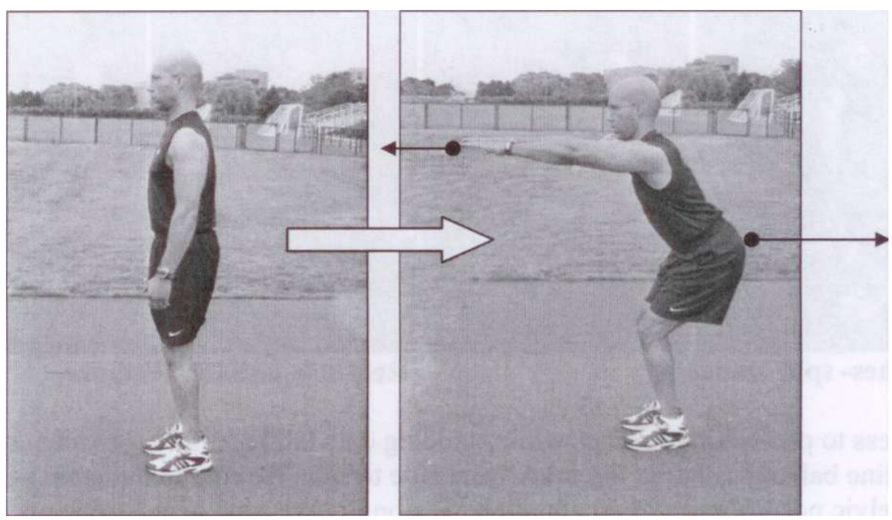
The client visualizes a connection from the arch of the foot, up the inside of the lower leg and out to the gluteus medius. They are then asked to imagine the line gently creating space under the arch of the foot, connecting to the medial aspect of the knee and gently being pulled laterally by the gluteus medius. The client maintains this connection through the movement pattern.

(Modified and adapted from specific cues as taught by Linda Joy Lee and demonstrated in The Pelvic Girdle 3rd by Diane Lee)

Anterior Reaches

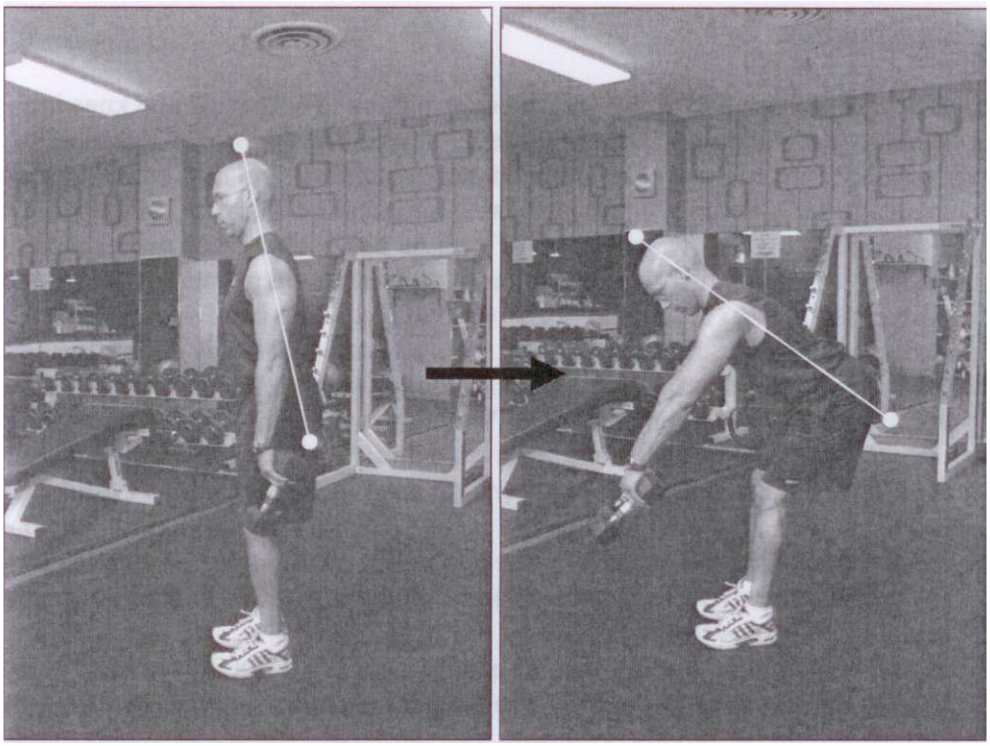
Hip restriction is perhaps one of the greatest contributors to both back and knee injuries and limits many individuals and athletes for ever developing the proper mechanics required to safely perform many movement patterns including but not limited to squats, lunges and deadlifts. Anterior reaches (AR) are a progression from the quadraped weight shifts and are one of the best ways I know of (weight bearing) to teach proper hip mechanics, specifically gliding the hip back into the socket and releasing through the posterior hip capsule. If an individual is unable to glide the hip back into the socket during a movement that requires hip flexion, they will compensate by either flexing the lower lumbar spine, shearing through the sacroiliac joints or creating potentially damaging rotation forces through the knees. While this will keep the orthopedic surgeons happy, it doesn't help any of our clients perform better. Even my elderly clients and individuals recovering from back surgery perform anterior reaches with modifications.

- Begin the pattern with a neutral spine and pelvic position and core activation. There should be slight flexion in the knees and this position should be maintained throughout the movement pattern.
- Begin by reaching the arms forward at shoulder height. As the arms are reaching forward the hips are driven back. The further the arms reach forward, the further the hips should be moving posteriorly (see arrows).
- Ensure core activation and maintain a neutral spine throughout the movement. Cue the individual to keep the hips relaxed and to spread through the sit bones.

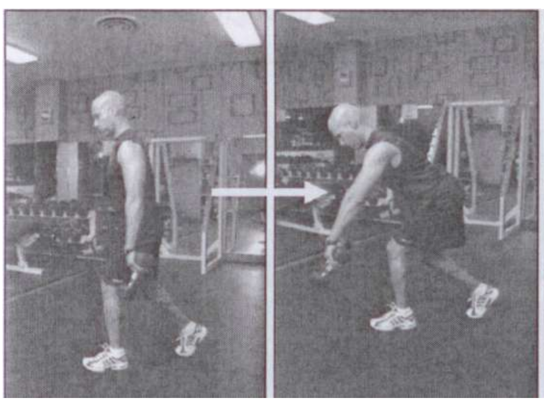


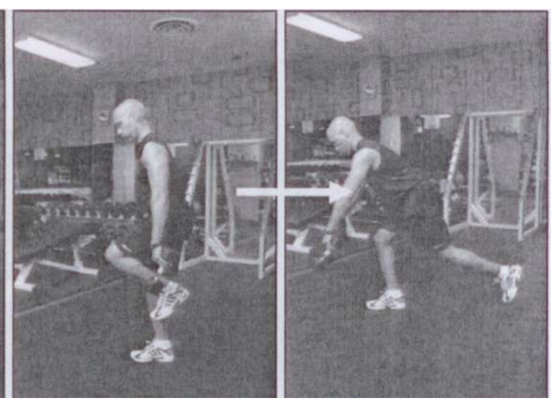
Anterior Reaches

Anterior reaches can be progressed by having the individual reach towards the waist and then finally towards the ankles. The pattern can also be performed in a split stance or unilateral stance making it more applicable for higher performing individuals. The pattern can be loaded with dumbbells (see below), medicine balls, cables or bands.



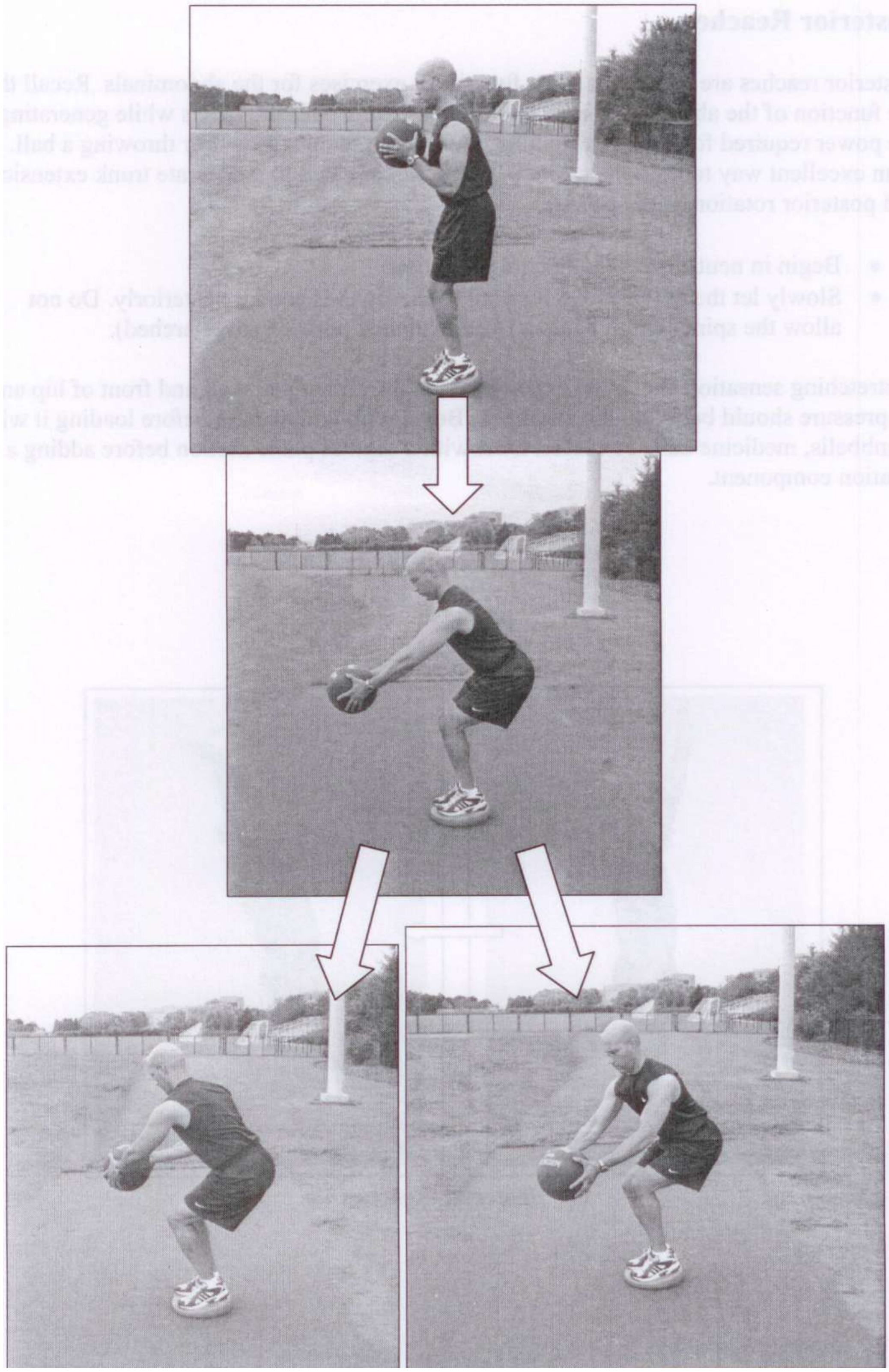
Reaches- bilateral





Reaches- split stance **Reaches- unilateral stance**

Progress to performing reaches while standing on a labile surface, holding dumbbells or a medicine ball and rotating the trunk from side to side. Be sure to maintain neutral spine and pelvic positioning and do not allow flexion or extension of the spine or elevation/abduction of the scapula. The hips and pelvis should shift in the opposite direction of the direction of the arms.



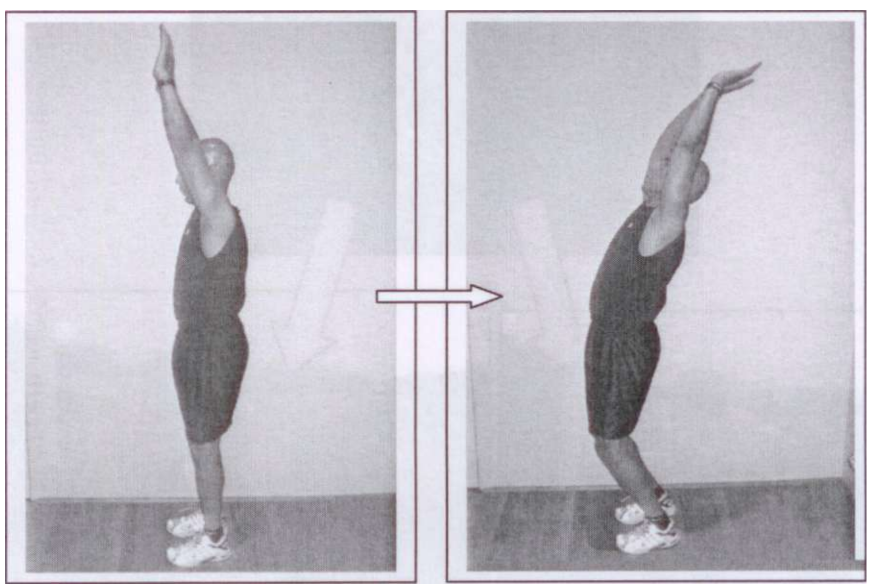
Reaches with Variations

Posterior Reaches

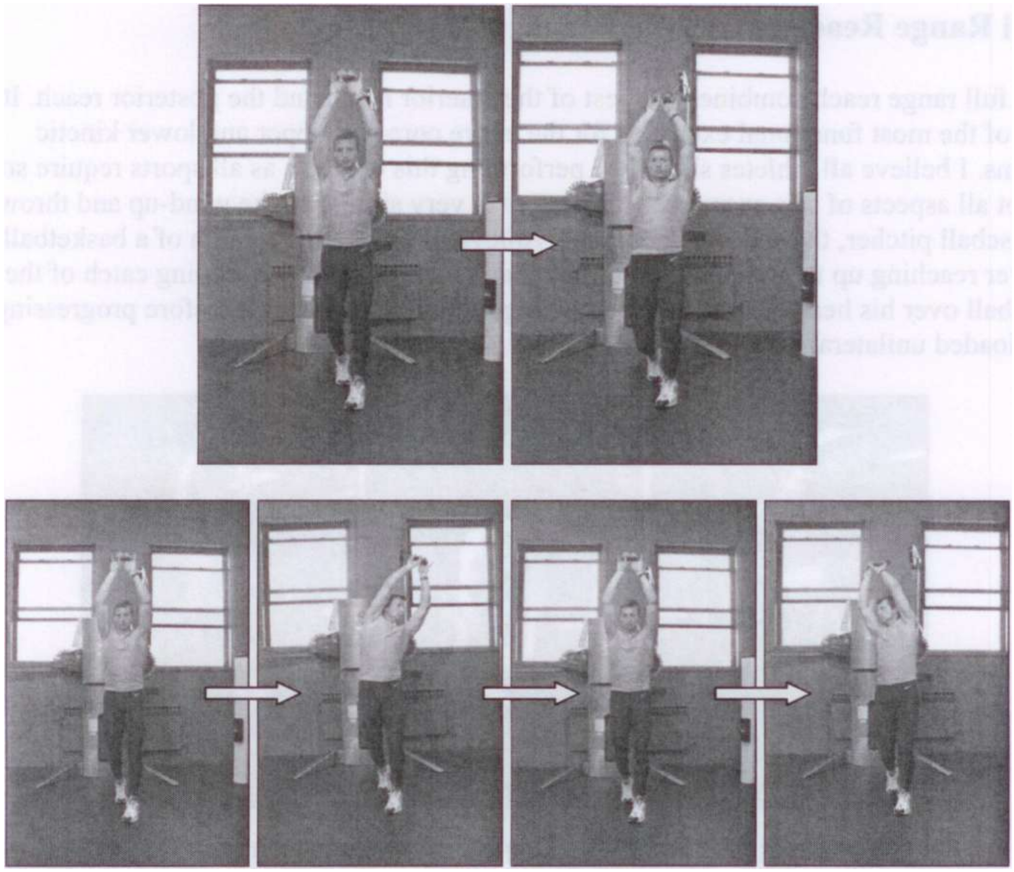
Posterior reaches are one of the great functional exercises for the abdominals. Recall that the function of the abdominals is to maintain the trunk over the pelvis while generating the power required for walking, running, swinging a tennis racquet or throwing a ball. It is an excellent way to train the entire core and flexor chain to decelerate trunk extension and posterior rotation of the pelvis.

- Begin in neutral spine with core activation.
- Slowly let the pelvis move forward as the trunk is arched posteriorly. Do not allow the spine to move into a hyperextended position (over-arched).

A stretching sensation should be experienced in the abdominal wall and front of hip and no pressure should be felt in the low back. Begin with bodyweight before loading it with dumbbells, medicine balls or cables. Start with a sagittal plane motion before adding a rotation component.

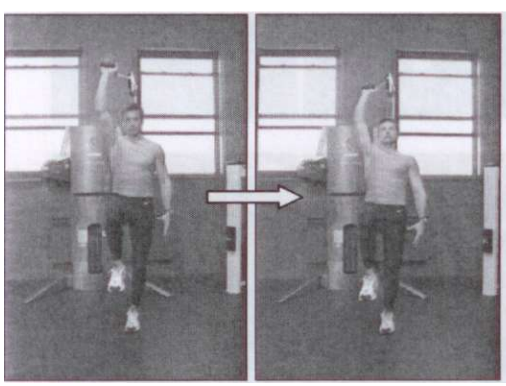


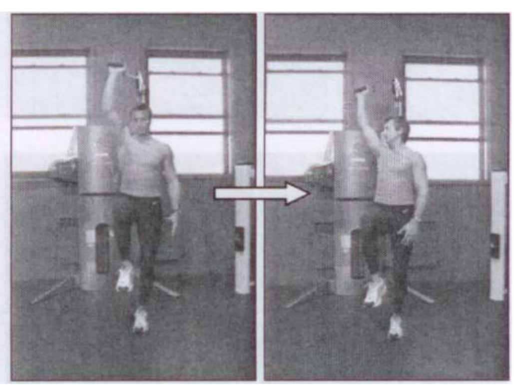
Posterior Reaches



Posterior Reaches - Variations

The single leg and single leg with rotation versions raise the level of core control that is required making it an excellent move for any overhead athlete including baseball pitchers, basket ball rebounders and volleyball players.

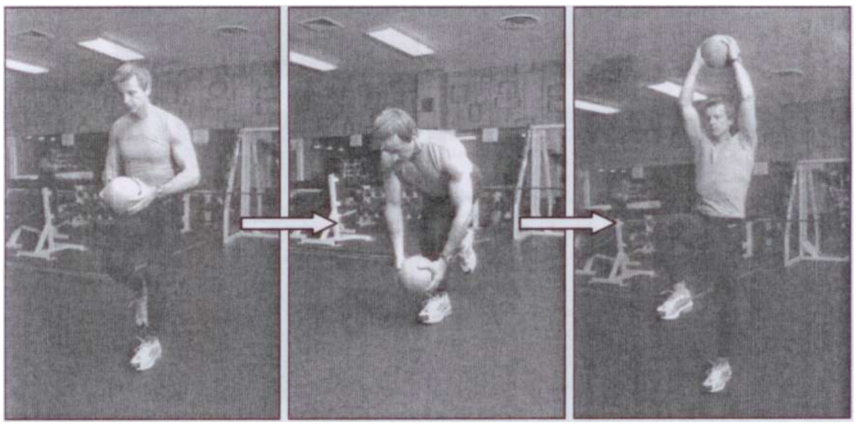


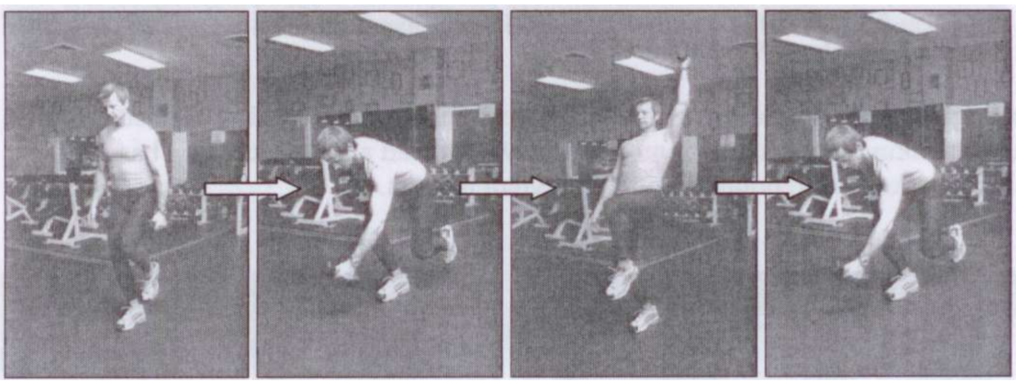


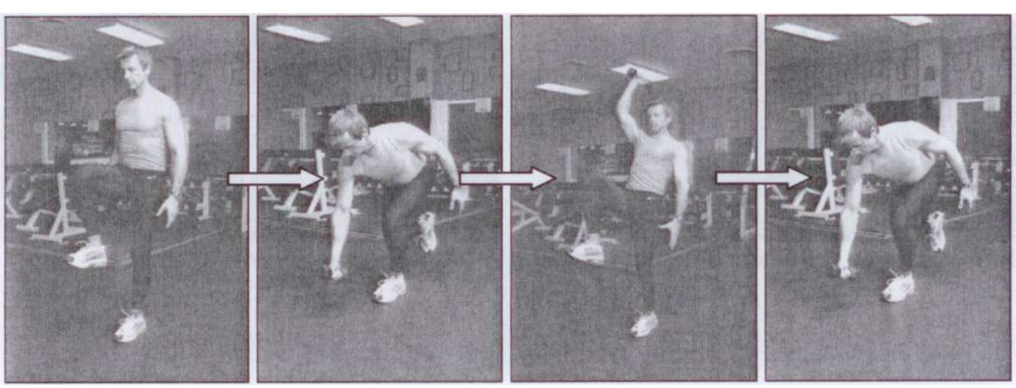
Unilateral Stance Posterior Reaches (sagittal) Posterior Reaches (rotational)

Full Range Reaches

The full range reach combines the best of the anterior reach and the posterior reach. It is one of the most functional exercises for the entire core and upper and lower kinetic chains. I believe all athletes should be performing this exercise as all sports require some if not all aspects of this exercise. This pattern is very similar to the wind-up and throw of a baseball pitcher, the spiking action of a volleyball player, the motion of a basketball player reaching up to grab a rebound or a wide receiver making a leaping catch of the football over his head. Begin with body weight in a bilateral stance before progressing to the loaded unilateral stance version.







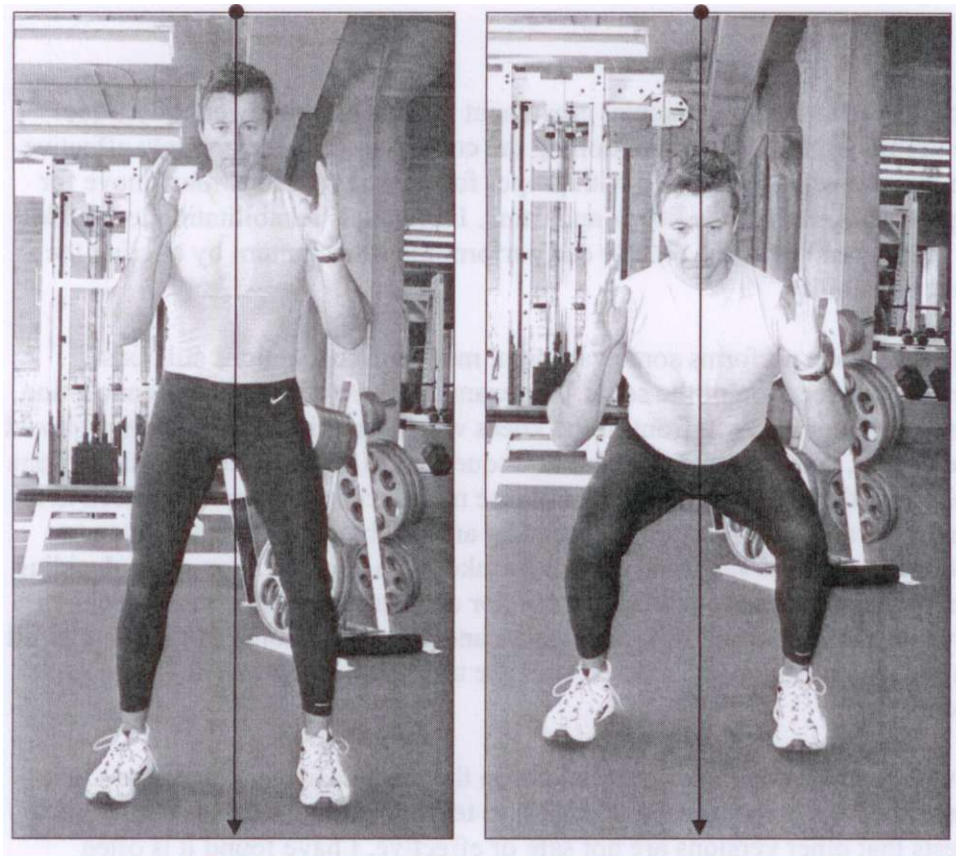
Full-Range Reaches, Variations

Squats

While often promoted as the fundamental movement pattern for the lower body, squat patterns are extremely effective at conditioning the core as well. It is extremely effective at loading the hip and when performed with proper form, is a great functional move for strengthening the stabilizers of the pelvis and trunk. Individuals rehabilitating low back, hip and knee injuries and even the elderly can perform the squat pattern by altering the depth and level of stability.

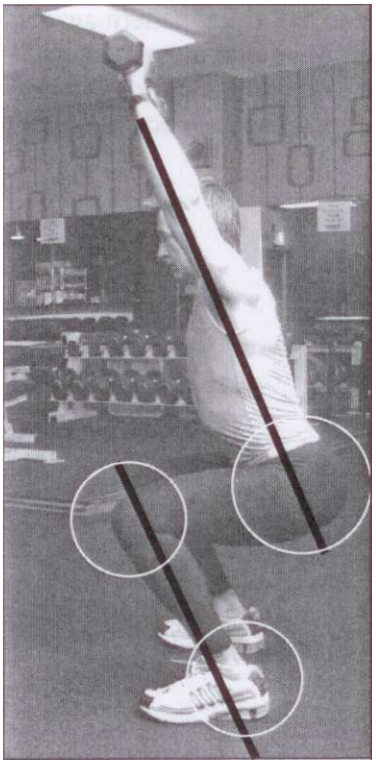
While virtually everyone performs some variation, many misconceptions still exist regarding the proper execution of the squat. For example, there is still the misconception that the knees should not move in front of the knees when squatting, the individual should look up as they squat, and the gluteals should be squeezed as the individuals lifts up from the descent phase of the squat. While a few of these misconceptions were discussed in an earlier section, there are a lot of improper cues that are still being commonly given to clients. Additionally, several variables need to be taken into consideration when deciding which version of the squat to use with a client. Prior exposure to the exercise, level of flexibility, level of motor control, body awareness and desired outcome of the exercise all play a role in the type of squat and specific cues the trainer or coach will decide to use with their client.

This section will evaluate and make suggestions on the most basic version of the squat- the parallel squat, as this is the safest and easiest to teach most individuals. While this in no way suggests that other versions are not safe or effective, I have found it is often difficult to teach even the basic versions to most individuals. Although many individuals may choose to perform Olympic squats, powerlifting style or ballet type squats, many of the biomechanics that are listed below will apply to other versions as well.



Squat Evaluation (Anterior View)

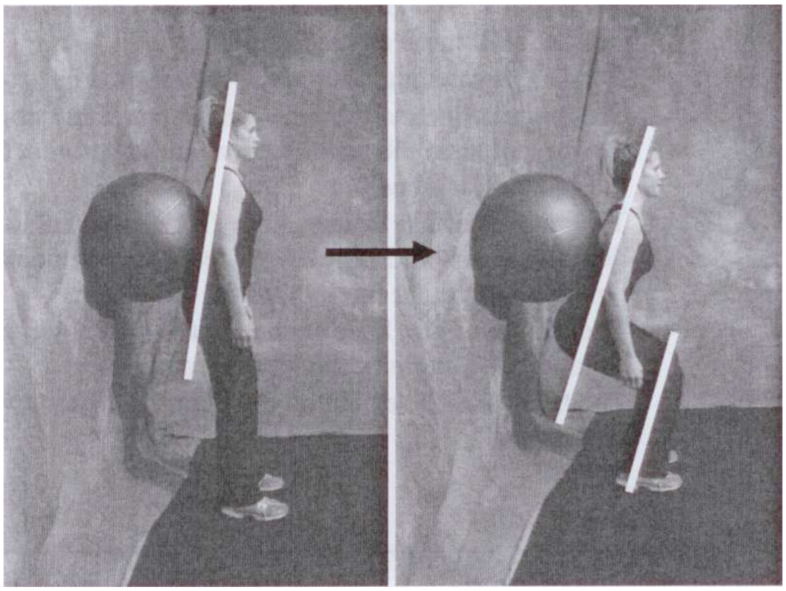
- Begin with feet approximately shoulder width or slightly wider apart.
- Hands are held in front of body.
- The head, trunk and pelvis should be in neutral position to begin and remain relatively stationary throughout the motion.
- Head and eyes should remain level with the horizon- do not look up as this encourages thoraco-lumbar extension.
- Core activation should be maintained throughout the motion.
- Trunk and pelvis should fall equidistant between feet.
- The knees should track in the same plane as feet (knees should track approximately between digits 1-3 of the foot).
- The knees should not deviate medially (adduction) or laterally (abduction) at any point throughout the motion.
- The tibia (lower leg) and feet should remain neutral throughout the movement.
- Heels should remain on the floor throughout the motion.
- Squat until thighs are approximately parallel or slightly below for most individuals (depth of squat depends on hip flexibility).



Squat Evaluation (Lateral View)

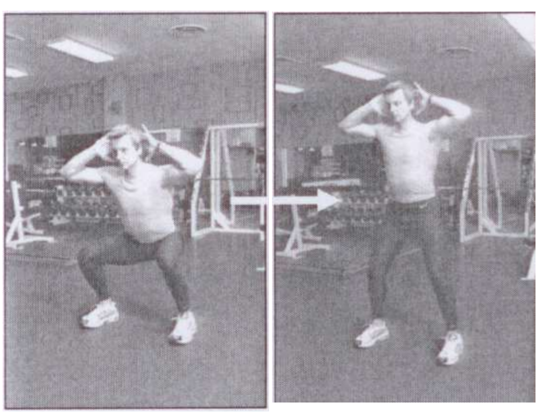
- Head, trunk and pelvis should remain neutral throughout motion.
- Maintain the arms at level appropriate for the individual (at the level of the waist for a beginner or overhead for more advanced trainees).
- Head and eyes should remain level with the horizon.
- The angle of inclination between the trunk and tibia (lower leg) should be nearly equal at the bottom of the squat (black lines).
- The amount of hip flexion, knee flexion and ankle dorsiflexion should be relatively equal and remain equal to each other throughout the movement.
- The degree of hip, knee and ankle flexion should be equal at the bottom of the movement (circles).
- The heels should remain on the floor throughout the movement.

A variety of squat patterns can be employed beginning with the ball squat pattern against the wall. Spine and pelvic position should remain neutral throughout the movement and the core should be activated throughout the pattern. Note the angle of inclination (white line) between the lumbo-pelvic-hip complex and lower legs remains nearly equal at the bottom position of the movement.

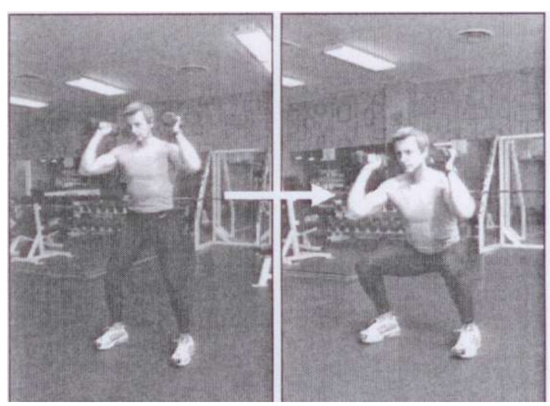


Ball Squat against the Wall

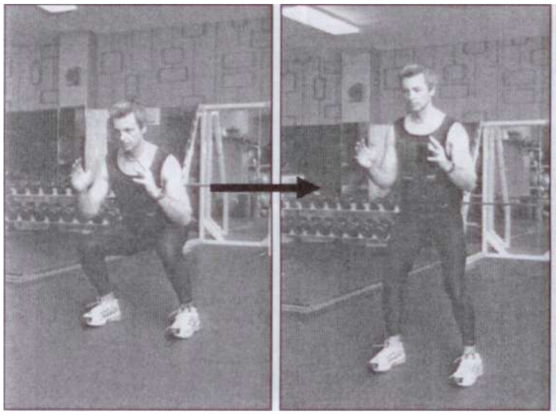
Progress to the unsupported squat pattern performed with body weight and hands behind the head. Increase the resistance by holding a pair of dumbbells at shoulder height, wearing a weighted vest or holding a set of cables.



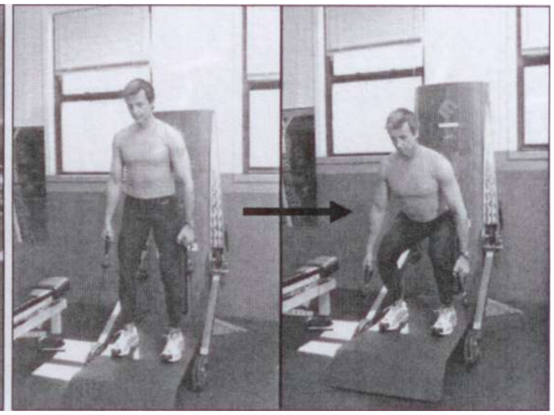
Squat with hands behind head



Dumbbell squat

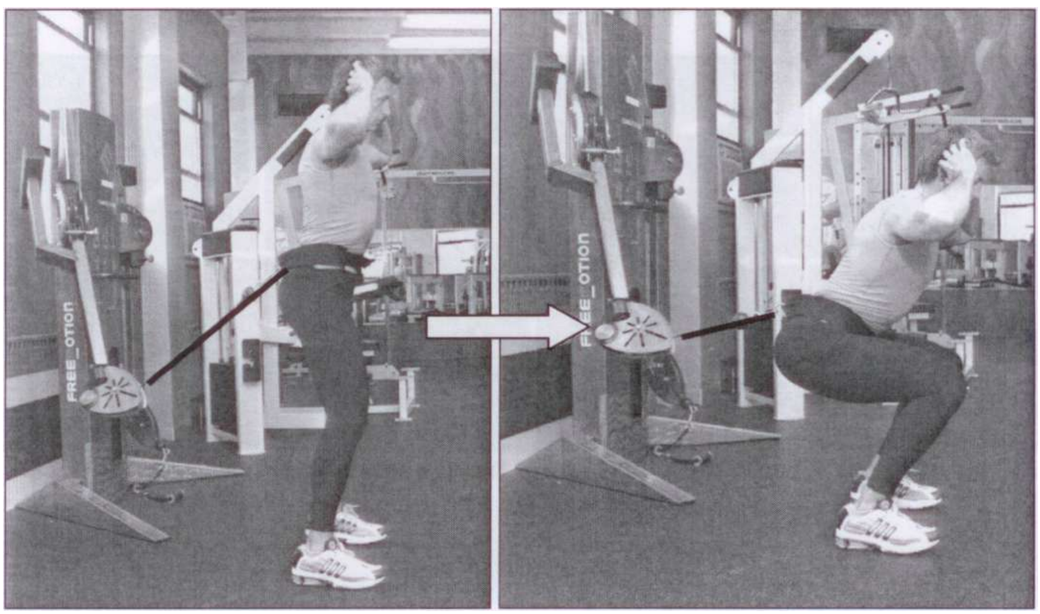


Squat- weight vest



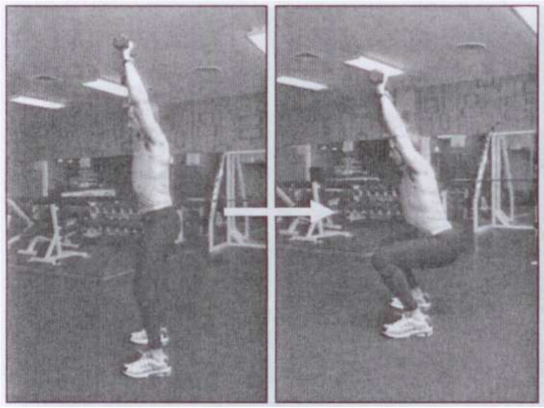
Squat- cable machine

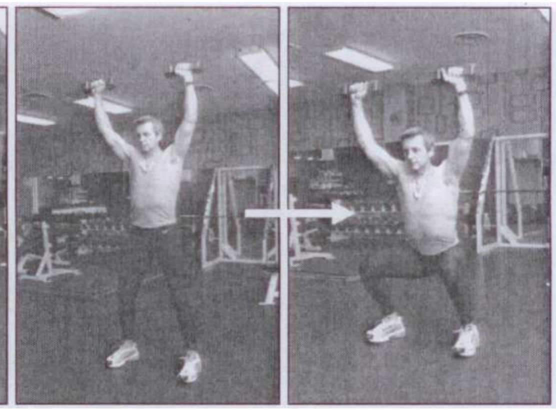
The squat pattern can also be loaded with bands or a cable apparatus which significantly increases activation of the core and lower extremity stabilizers. Maintain core control and proper alignment between the trunk and tibias- do not allow the trunk to arch, lean forward or back.



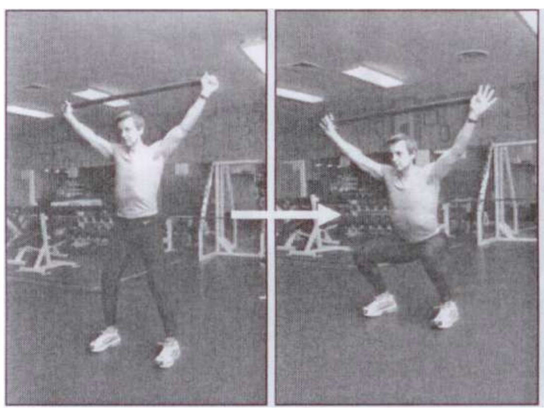
Squat with cable attachment

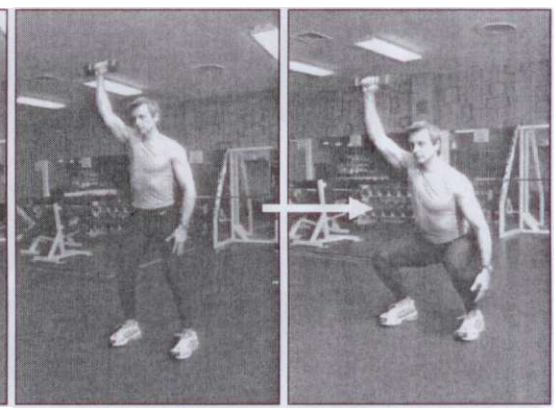
The overhead squat pattern increases the activation of the core musculature since the weight is supported at arms length above the body. Any overhead version requires significant flexibility of the shoulder and hip complex to allow the spine and pelvis to remain in a neutral position so these positions should be closely monitored. Those with less shoulder flexibility can keep their arms at shoulder height and those with hip restriction can modify the depth of their squat. Begin with body weight squats before adding any resistance and maintain core activation throughout all versions.


Overhead Squat, Lateral View

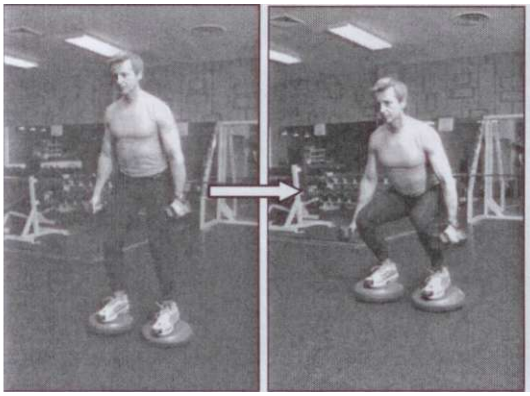

Front View

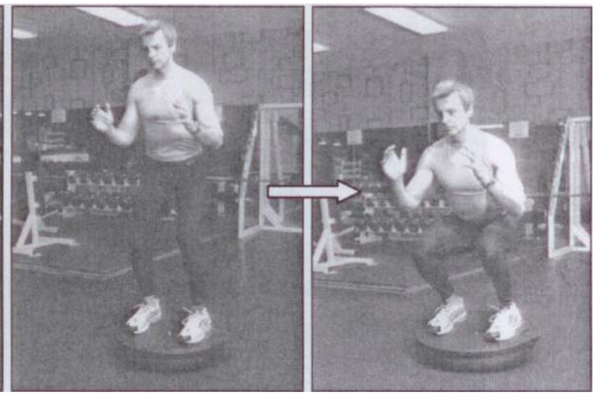
The overhead squat with a body bar requires even greater flexibility of the shoulder complex since it keeps the upper extremities in a completely flexed position. Rarely do we lift symmetrical loads in a static position, so performing this movement with asymmetrical loads as demonstrated below trains the body to deal with forces that more closely resemble the situations we are going to encounter in during activities of daily living, sports and occupational environments.


Bilateral Overhead Squat Pattern


Asymmetrical Overhead Squat

Performing the squat pattern while standing on labile equipment increases the proprioceptive challenge on the stabilization system of the core and lower extremities.

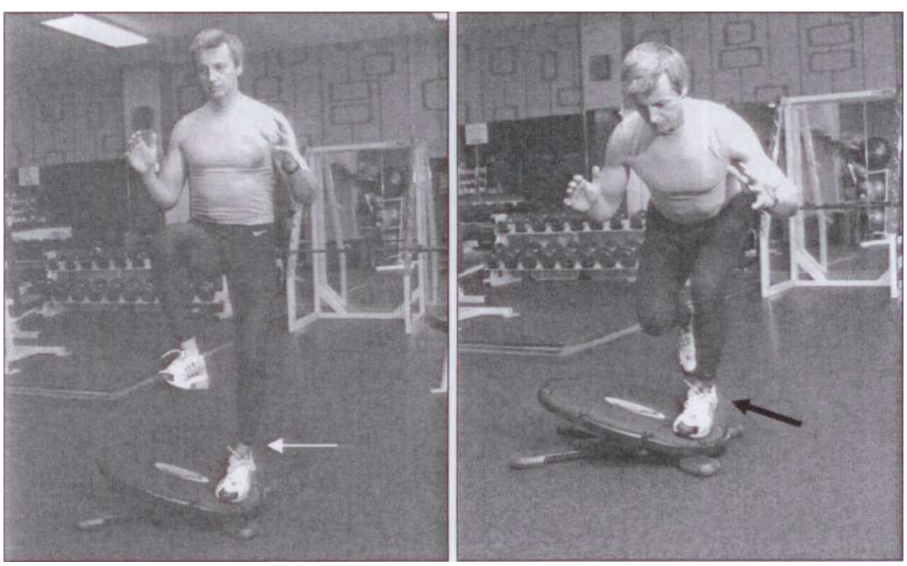




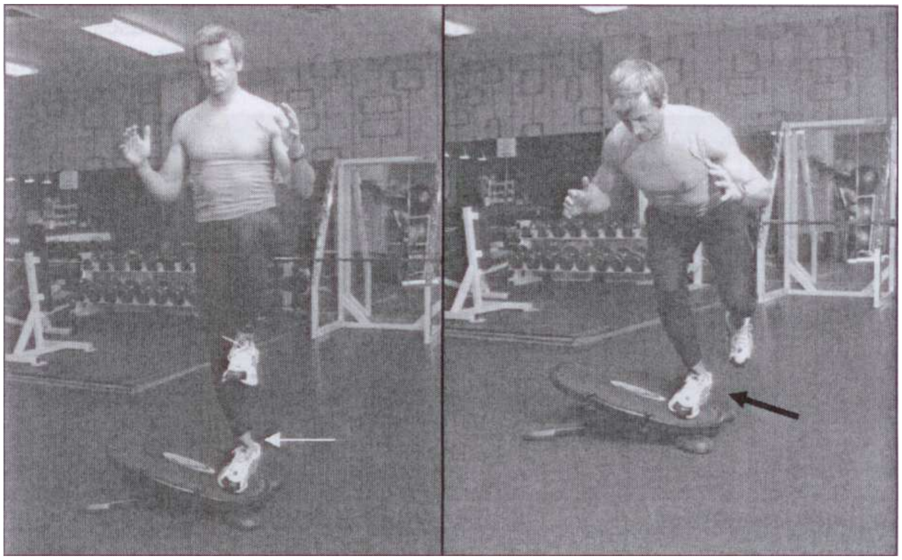
Stability squats- dynadiscs **Stability squats- BOSU**

Ankle Stability Squats

Single leg squats on a balance board or Reebok Core board are a fantastic way to train the entire lower kinetic chain and especially target the ankle stabilizers. Be sure the individual can maintain stability of the core and neutral spine position while standing on one leg prior to performing the squat movement. Challenge the muscles that are responsible for controlling inversion (inversion bias) of the ankle, specifically the peroneii longus and brevis, by performing the squat with the outer leg. Performing the squat with the inner leg challenges the muscles responsible for controlling eversion (eversion bias), specifically the tibialis posterior and tibialis anterior.



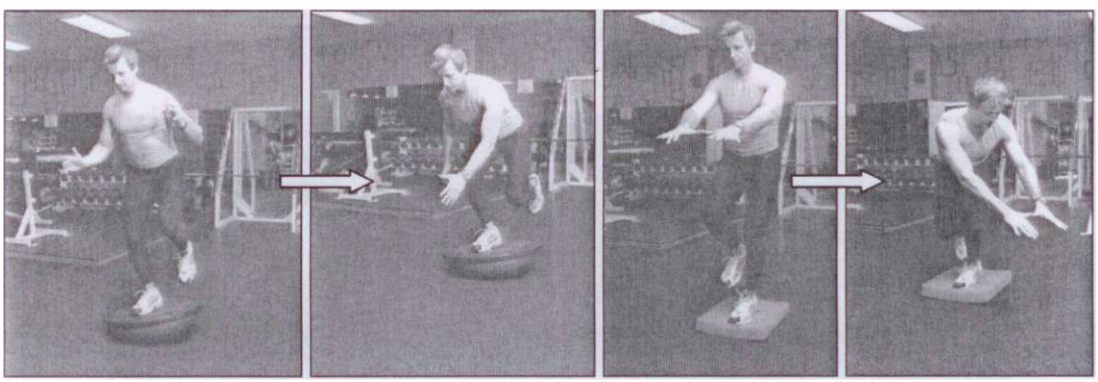
Ankle stability squats- inversion bias



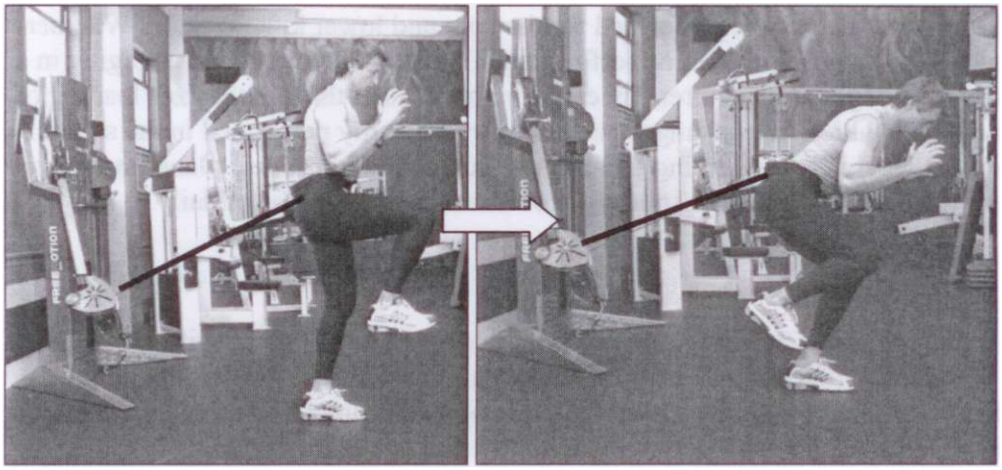
Ankle stability squats- eversion bias

Unilateral Squat Reach

The unilateral squat reach pattern is one of the most challenging patterns for the hip and entire lower extremity. Perform a single leg squat and reach in front or towards the stance side leg (internal hip rotation). Standing on a labile surface (BOSU or Airex pad) significantly increases the challenge to all the joints in the lower extremity and core.

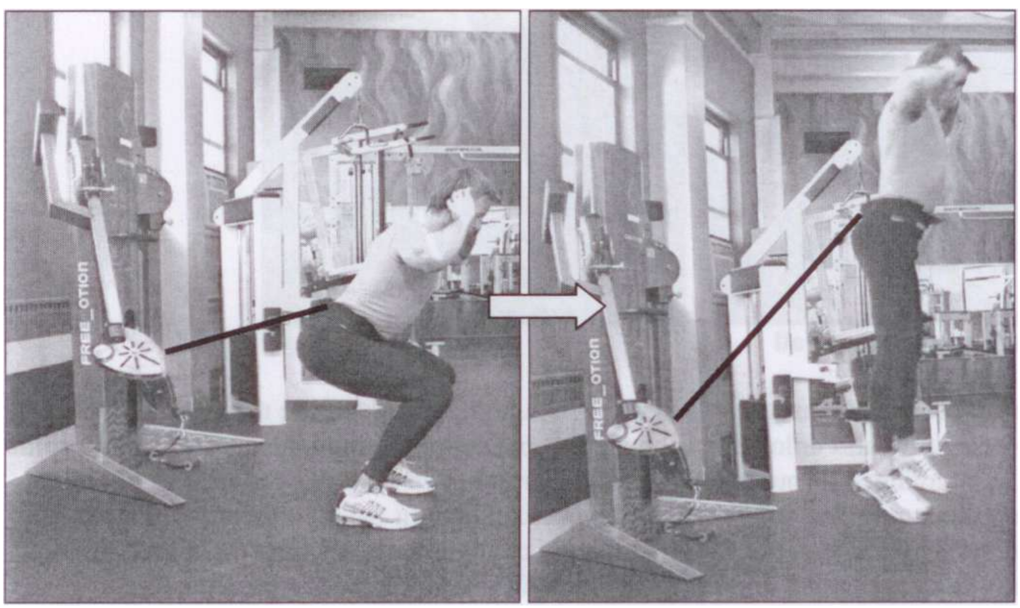


Single leg squats with a cable attachment dramatically increase the challenge of the exercise due to the constant resistance provided by the cable.



Single leg squat with cable resistance

For your athletes requiring increased challenge, squat jumps are extremely effective at developing dynamic strength and power through the entire lower limb. This pattern can be loaded with bands or cables for an increased demand on the system.

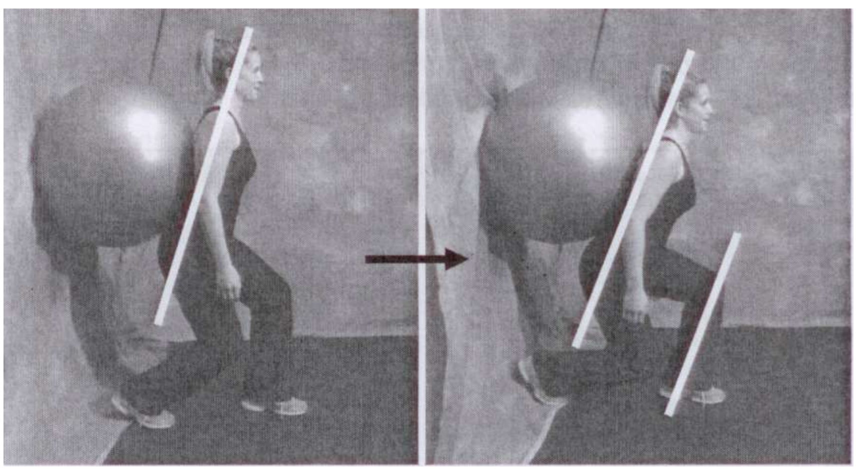


Squat Jumps- with cable

Lunge Patterns

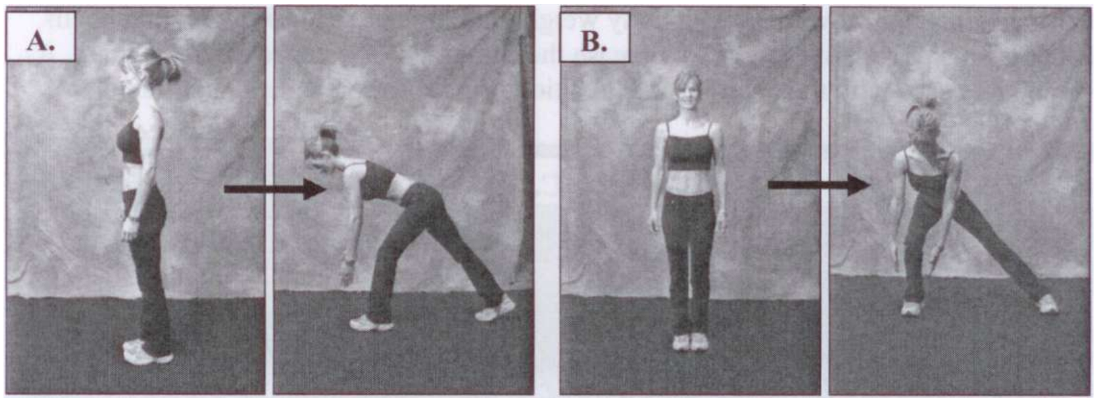
Lunge patterns are another effective way to train the core and are among the most functional exercises that can be performed for the core and lower kinetic chain. Whether picking up a child, bag of groceries or performing a lateral maneuver while engaging in a sporting activity, lunges are an extremely effective movement that emphasizes loading of the hip, knees and ankles. While lunges have been traditionally performed in the sagittal plane (bodybuilder style), performing them in the frontal and transverse plane improves hip function while benefiting most sporting movements and activities of daily living.

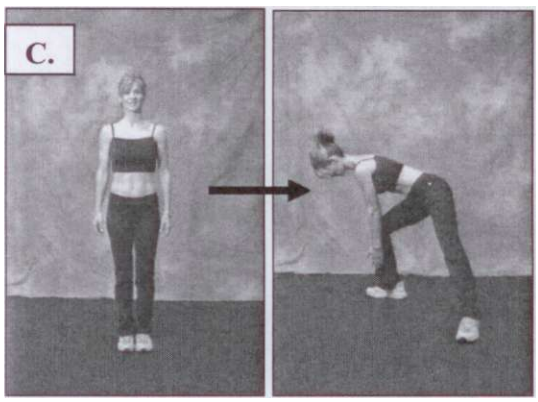
Individuals that are just learning proper positioning of the body or those with low back, hip, knee or ankle dysfunction can begin with the ball lunge before progressing to the unsupported versions. As with the squat, the angle of inclination (white lines) remains nearly equal between the lumbo-pelvic-hip complex and lower extremity.



Ball Lunge Against the Wall

Proper progressions begin with maintaining a neutral spine position throughout the loading (eccentric) and unloading (concentric) phases of the movement. The neutral spine position is maintained throughout the sagittal, frontal and transverse planes. By modifying the length and depth, nearly anyone can benefit from performing lunges. Decrease the length and depth for older clients or those with low back or hip restrictions while increasing the length and depth will benefit the more athletic individuals.





Figure

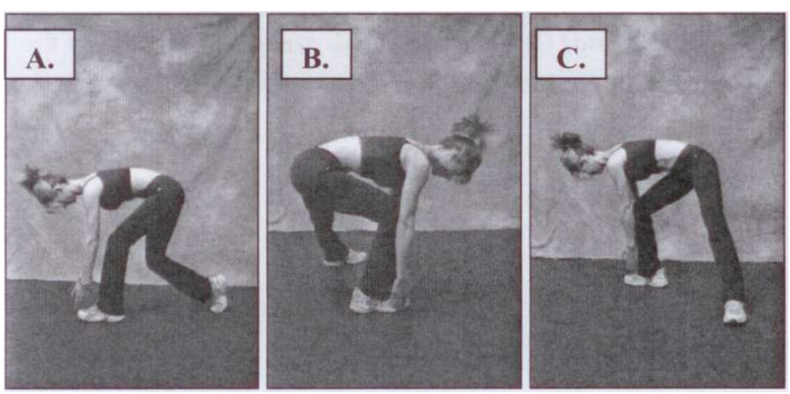
<u>Lunge pattern with neutral spine</u>

A. Sagittal plane

B. Frontal plane

C. Transverse plane

Once neutral spine position can be maintained, spinal flexion can be introduced to increase the eccentric loading through the spinal erectors. Flexion is an excellent way to condition sports specific patterns or movements of everyday life since spinal flexion is part of normal biomechanics. *However, this exercise is not appropriate for every individual and we only use it with clients that are able to demonstrate neutral spine posture through a variety of movement patterns and have adequate ranges of motion through the hip joint. See caution below.*



<u>Lunge patterns with spinal flexion*</u>

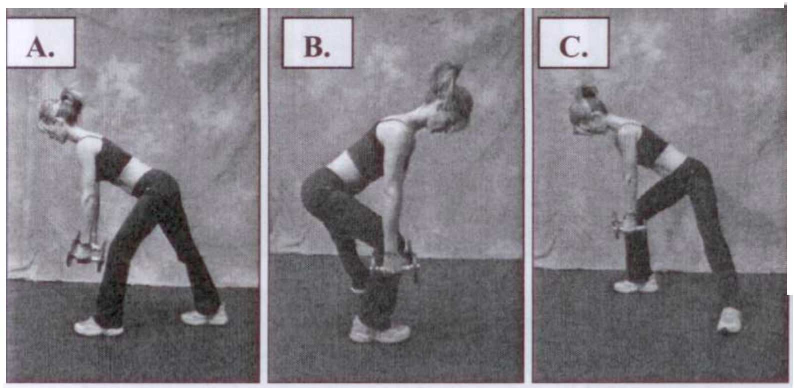
A. Sagittal plane

B. Frontal plane

C. Transverse plane

Caution should be taken with individuals with a history of low back pain and/or conditions such as osteoporosis since increased spinal flexion dramatically increases loads to the discs and other soft tissue/osseous structures of the spine.

After mastering the movement with body weight, lunges can be loaded with dumbbells, medicine balls or resistive bands to increase the demand on the entire extensor chain. As with above, begin with the neutral spine position prior to introducing spinal flexion.

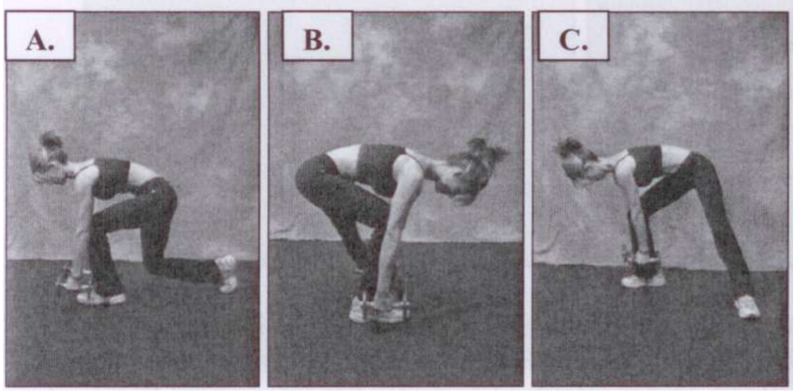


<u>Dumbbell lunge patterns with neutral spine</u>

A. Sagittal plane

B. Frontal plane

C. Transverse plane



<u>Dumbbell lunge patterns with spinal flexion</u>

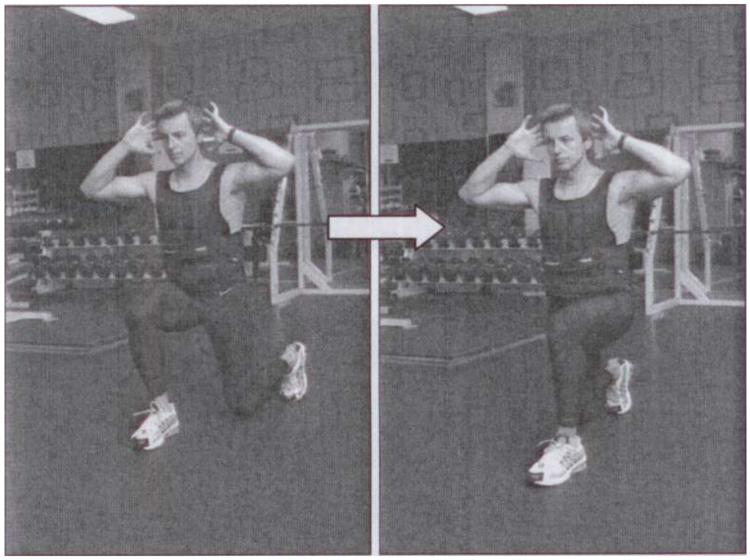
A. Saggital plane

B. Frontal plane

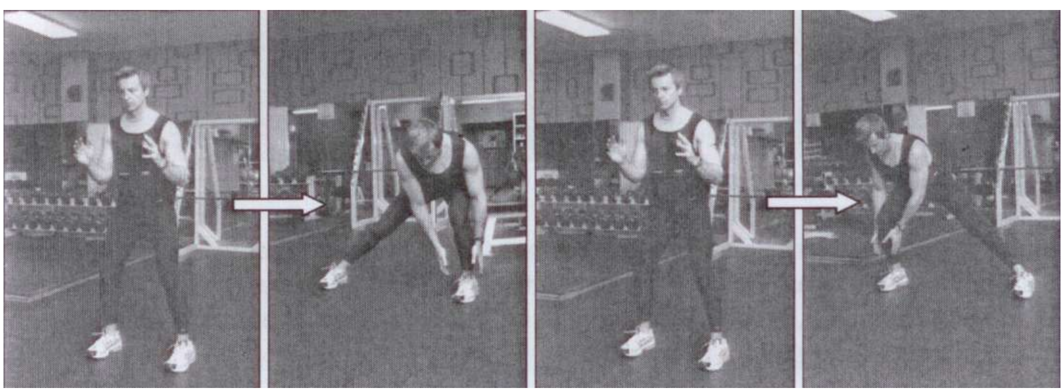
C. Transverse plane

Note: Maintain low external loads with any movement pattern performed with spinal flexion. Ensure that your client is pain free and can perform neutral spine versions prior to adding a flexion component as this motion can put the spine at risk for overload injuries in at risk clients especially when loaded. Since the risk does not outweigh the benefit, do not perform spinal flexion with loads greater than 10% of the individual's bodyweight

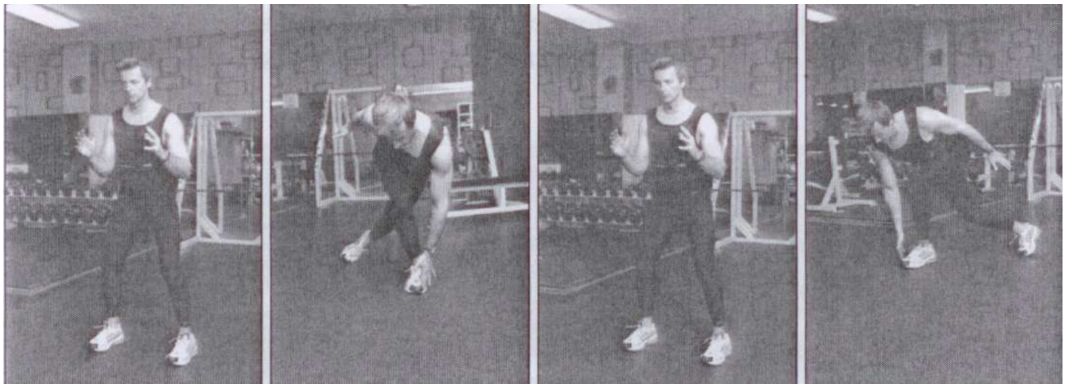
Several variations of the lunge can be performed by modifying depth, steps, reaching positions and resistances. In all versions, maintain core activation and focus on proper deceleration mechanics.



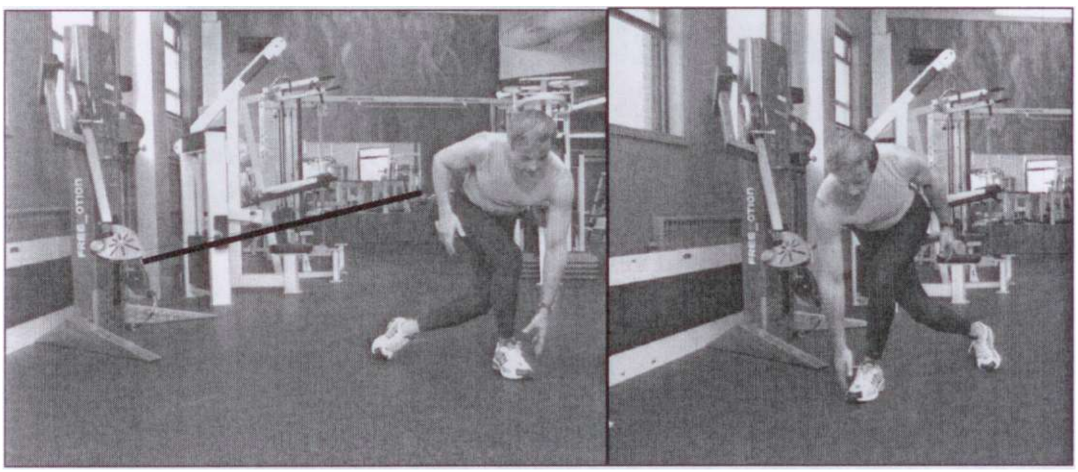
Lunge- weight vest with hands behind head



Lateral lunge with weight vest

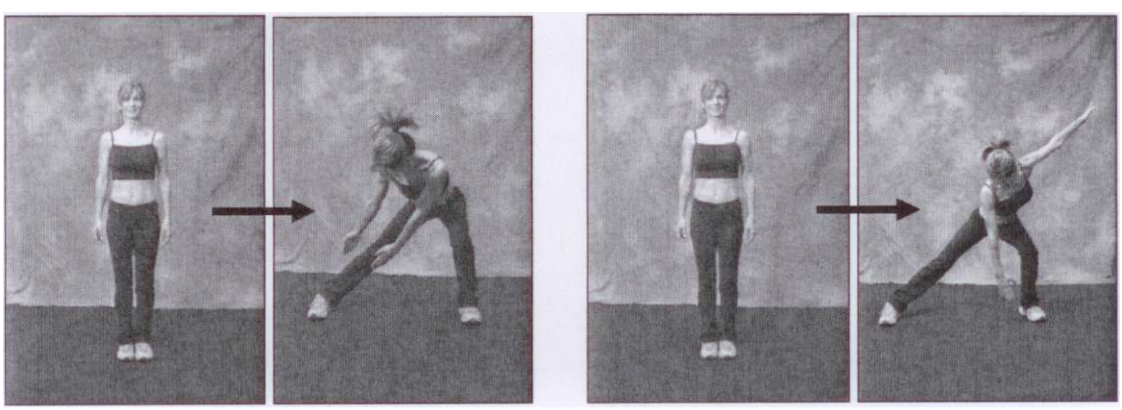


Cross over lunge with reach



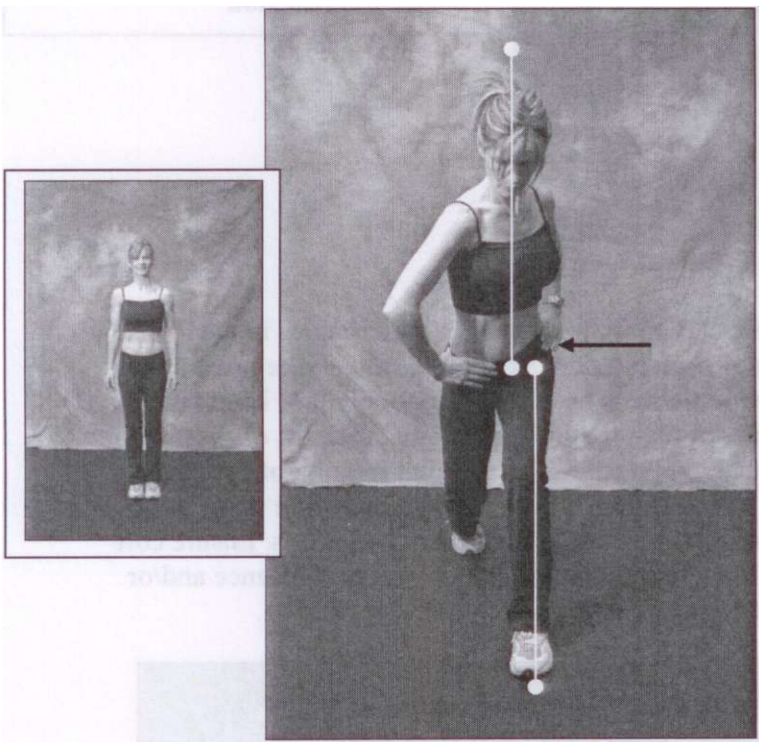
Cross over lunge with cable resistance

Alternate reaching patterns can be employed to increase the rotational loading of the hip while improving functional flexibility through the trunk and upper extremity. While challenging on their own, these versions are excellent to include as part of a functional warm up for sports or higher level activities.



Lunge With Rotation

I utilize the lunge with rotation to improve internal hip rotation (forward hip) while working on deceleration mechanics of the forward leg. The individual begins with neutral spine and core activation and then precedes to taking a step forward while rotating to the side of the forward leg. After deceleration and stabilization, the individual pushes through the hip and thigh to return to the starting position. The rotation comes from the hip with minimal rotation from the spine. Although both are necessary part of normal biomechanics, there should be minimal rotation at the knee or pronation through the ankle during the motion. Hold the arms on the hips to begin and progress to holding them behind the head and finally straight out in front of the body. This movement can then be loaded with dumbbells or medicine balls for an increased challenge.

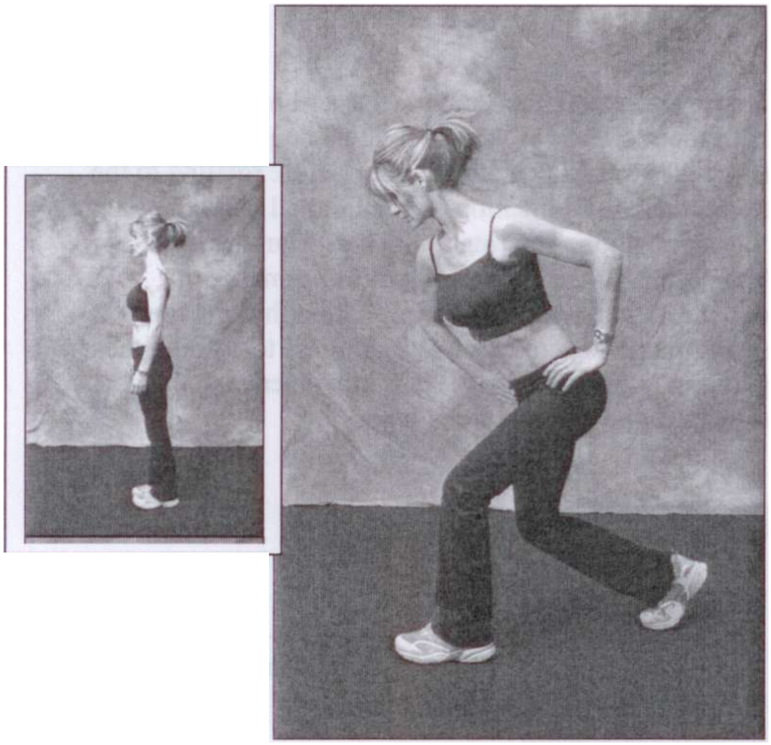


Head and spine neutral (top white line)

Rotation occurs at the hip (arrow)

Alignment is maintained through the hip, knee and ankle (bottom white line)

Lunge with rotation (anterior view)



Head neutral

Rotation occurs at the hip

Hip flexion with neutral pelvis

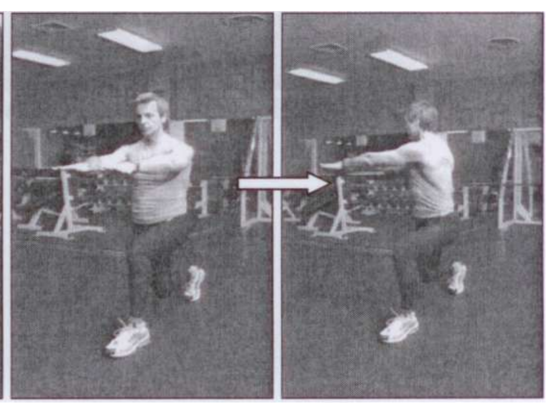
Knee flexion

Ankle dorsiflexion

Lunge with rotation (lateral view)

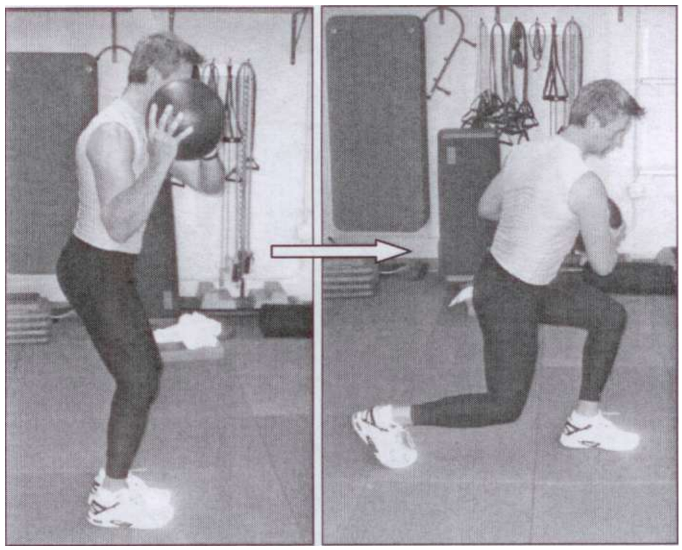
The lunge with rotation is an excellent way to train stabilization mechanics in the lower extremity, while subsequently training trunk rotation. Begin in a split stance position (as wide as the individual can control) with the arms held at shoulder height or level with the floor. Rotate the trunk towards the side of the forward leg (internal rotation of the hip). Return to beginning position and repeat to opposite side (external rotation of the hip). Rotation should occur on a constant axis with no shifting in the spine while simultaneously maintaining the alignment in the ankle, knee, hip and pelvis. Ensure core activation throughout the motion. If the client has difficulty maintaining balance and/or stability, shorten the length of the stance and/or the amount of trunk rotation.

Lunge with internal rotation



Lunge with external rotation

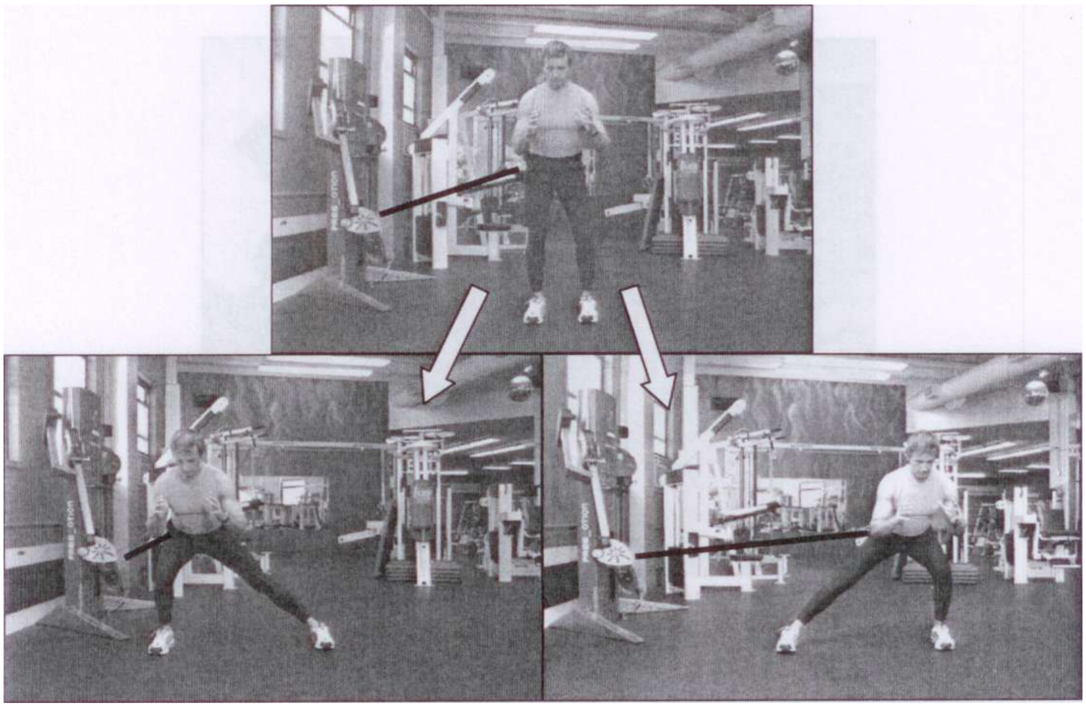
The lunge with rotation can be progressed by adding a medicine ball chop which further emphasizes deceleration of the trunk and hips. Begin in a neutral spine position, core activation and hold a medicine ball over the opposite shoulder from the stepping leg. Step out into a lunge while simultaneously chopping the ball towards the hip of the forward leg. Decelerate the motion (hold for a second) and return to the starting position. Perform the determined number of repetitions and repeat the pattern on the other side.



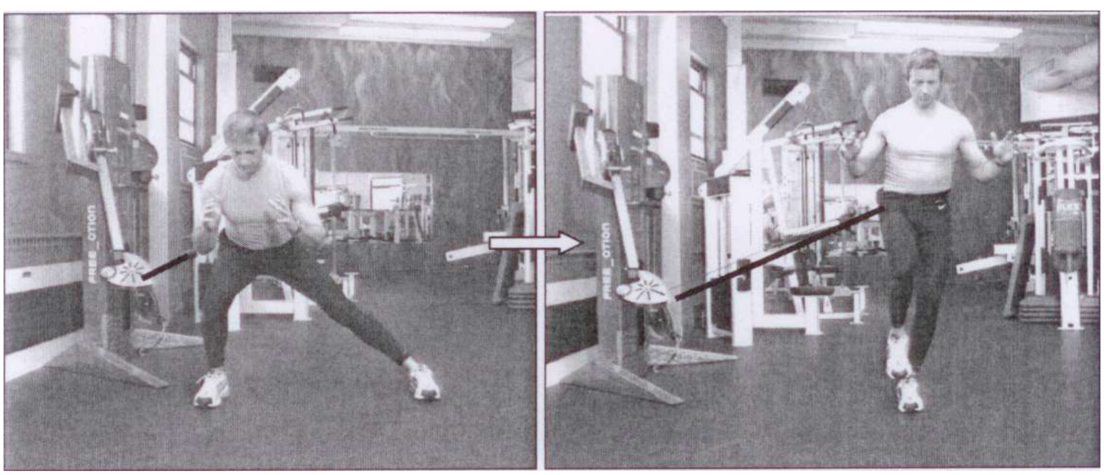
Rotational lunge with medicine ball chop

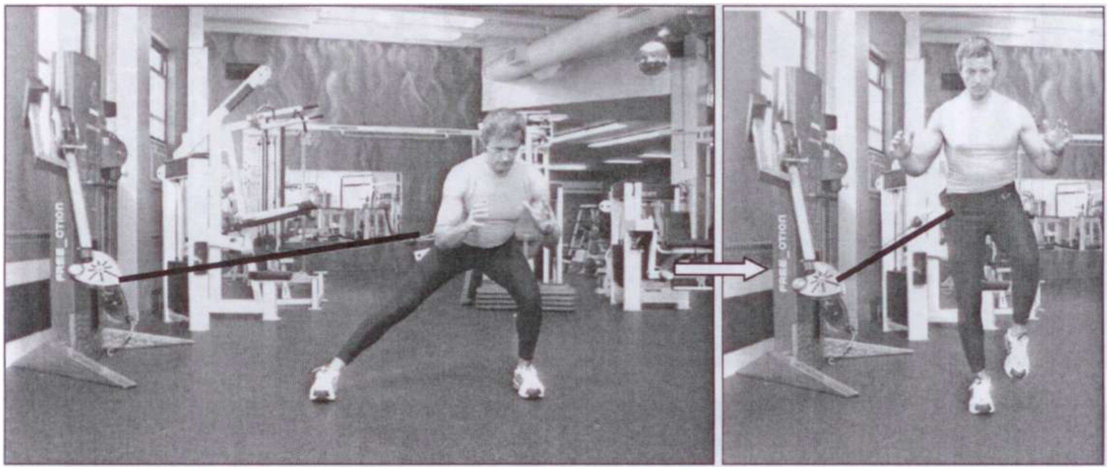
Cable Resistance Lunges

The Free Motion machine makes loading lunges functional and fun. Be sure to maintain core activation, neutral trunk alignment and focus on deceleration mechanics throughout the movement patterns.

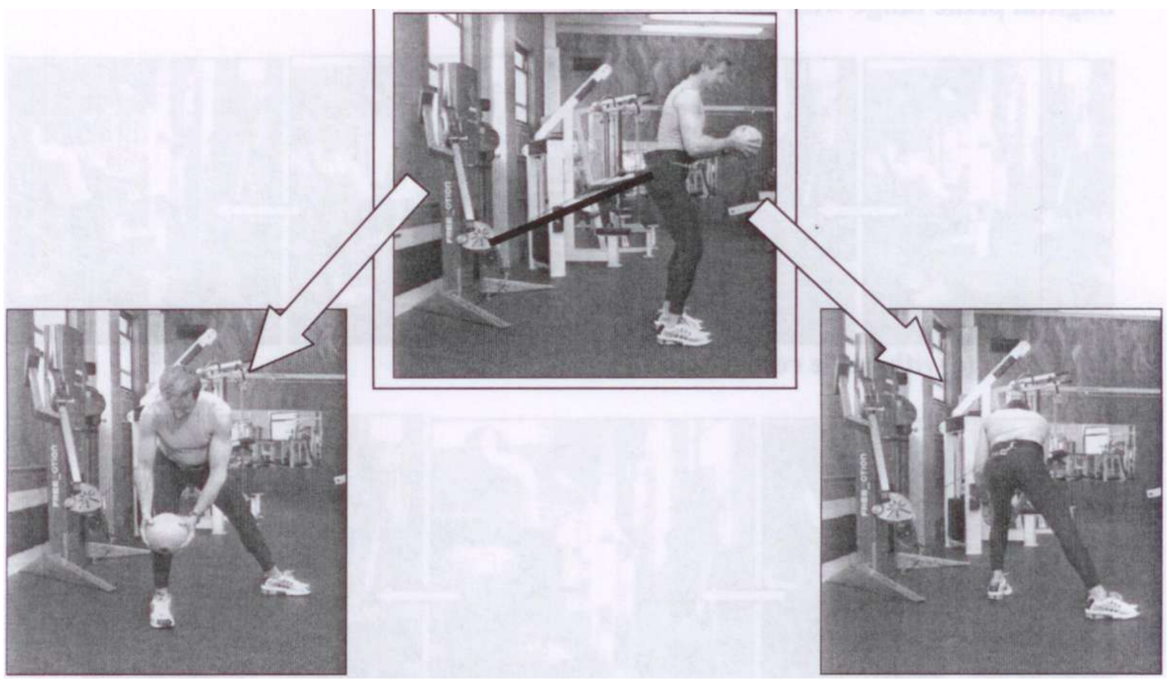


Frontal plane lunge with cable resistance



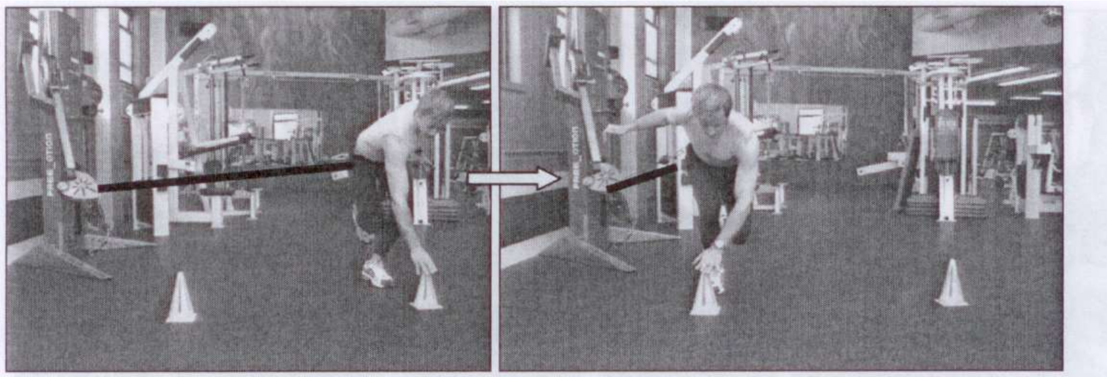


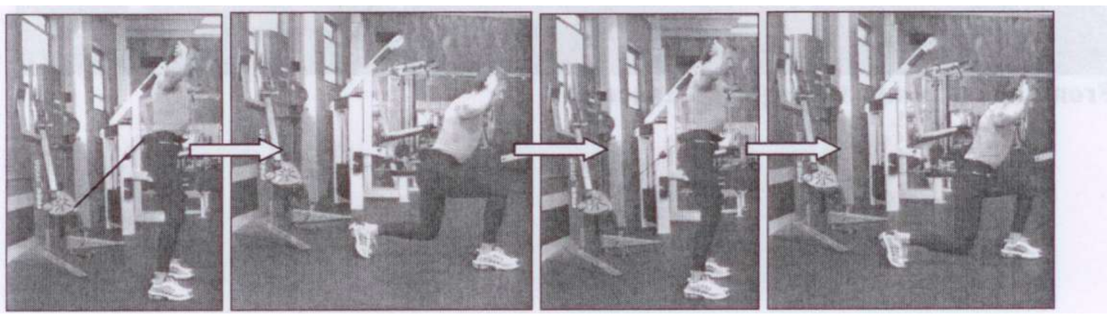
Frontal plane lunge to single leg stance



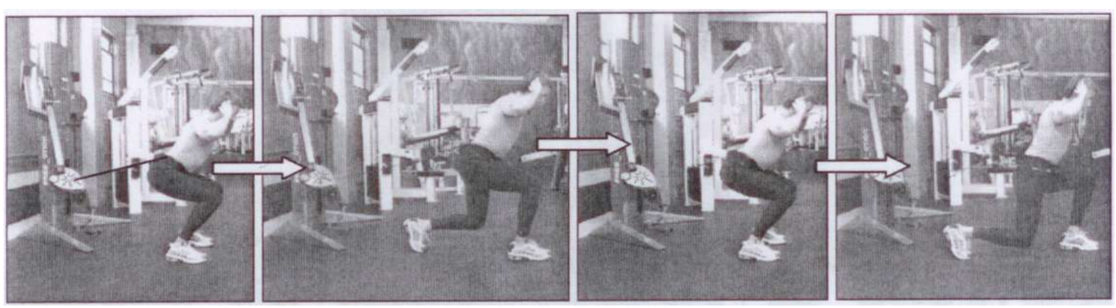
Transverse plane lunge with medicine ball reach

After the individual can stabilize in unilateral stance against the cable resistance, progress to the dynamic lateral lunge (a.k.a. skaters) with a contralateral reach. Continually monitor to ensure proper form as the movement places a tremendous amount of stress on the lateral chain.

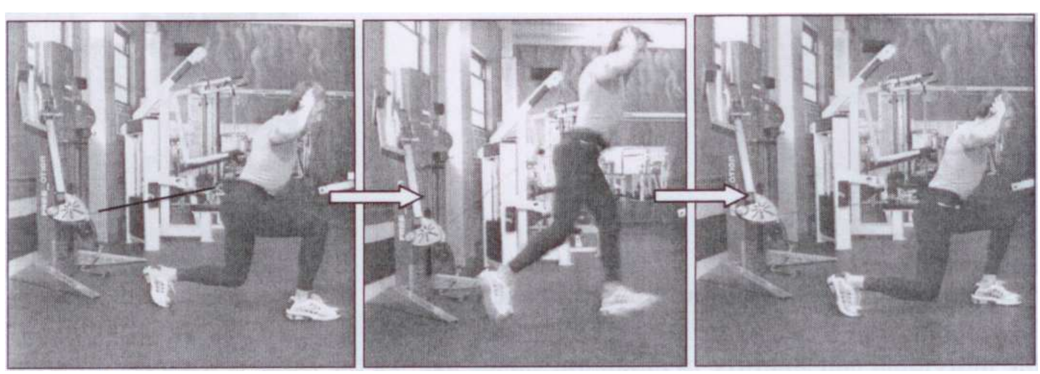


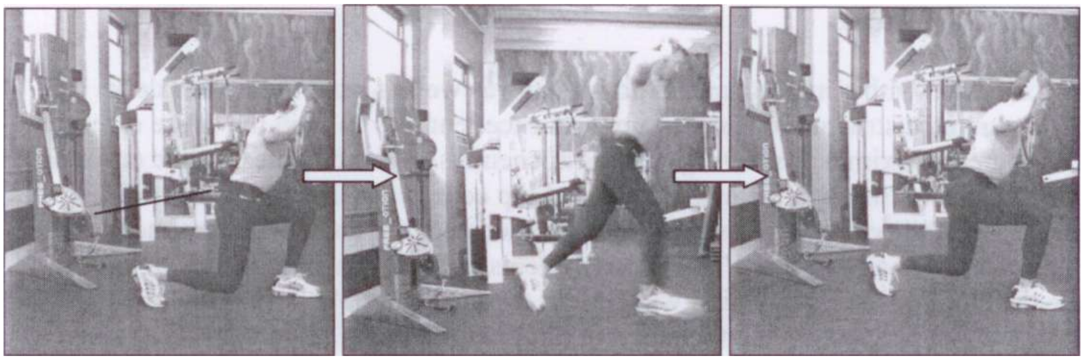


Sagittal plane lunge with cable resistance



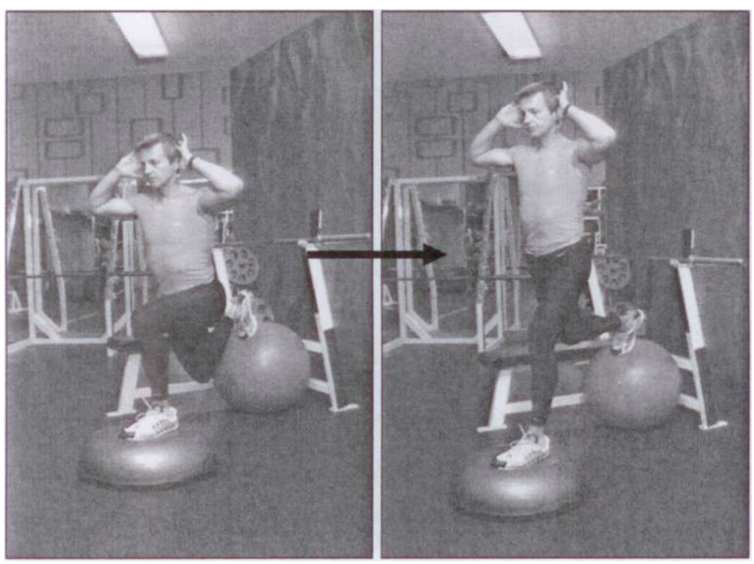
Squat-lunge with cable resistance





Dynamic split squat with cable resistance

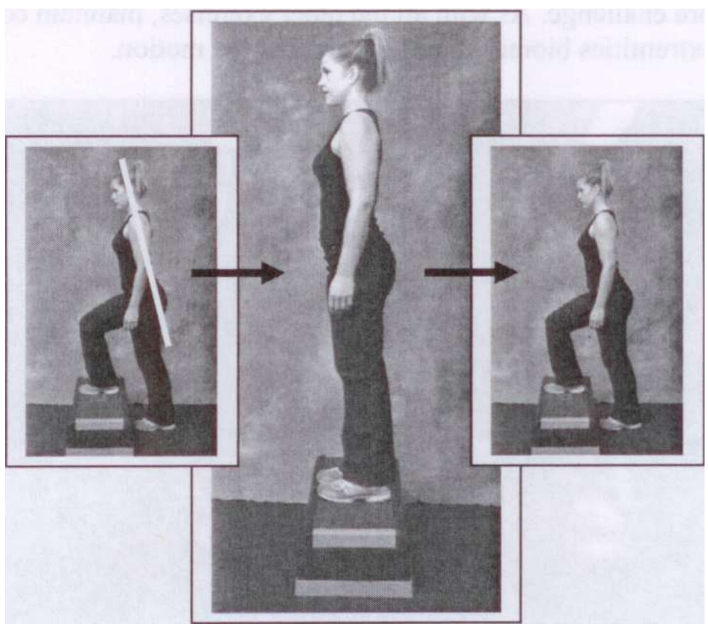
Some exercises are performed simply because they are challenging and fun. The lunge performed on a BOSU and stability ball is a high level exercise that challenges the entire core and lower extremity. Because it is performed on 2 labile surfaces, there is a high demand on the entire proprioceptive system and should only performed by higher level clients. Brace the stability ball against something that will not move. Place one leg on the BOSU and the back leg on the stability ball. Place arms at side, at waist or overhead for those requiring more challenge. As with all the other exercises, maintain core control and proper hip/lower extremities biomechanics throughout the motion.



Step Ups/ Step Downs

Everyone deals with climbing up and down stairs as well as stepping up and down off curbs and related structures. The step up is an excellent way to train the entire extensor chain (gluteus maximus, hamstrings and gastocnemius/soleus complex) while ensuring proper mechanics through the ankle, knee and hip complexes. Nearly every client, regardless of ability, can perform step ups- smaller steps for those with weakness and instabilities (even as small as 1" for elderly clients or those rehabbing from an injury) while the more athletic population will benefit from a higher platform. The height of the step should not be greater than the range of hip flexion motion since this will create compensations through the lumbo-pelvic and/or knee regions.

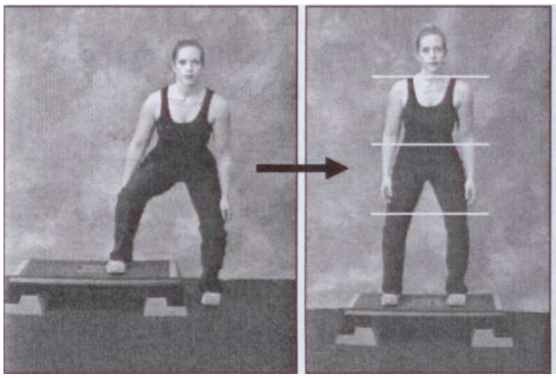
The basic version (sagittal plane) begins with a neutral spine (white line), core activation and ankle, knee and hip alignment as the individual steps onto the platform and back down. There should be no deviation in the lower extremity or compensation in the trunk (viewed as lateral shifting, shearing or rotation).



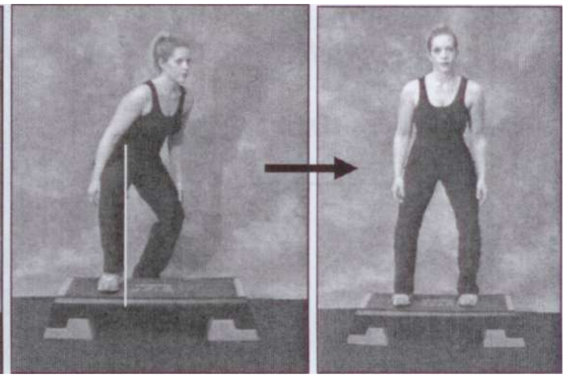
Basic Step up

Step ups can also be performed in a multiplanar fashion by including the frontal and transverse plane versions. Be sure to monitor for the following alignment:

- Shoulders, pelvis and knees should remain level (horizontal lines)
- Spine remains neutral with core activation
- Maintain alignment of the hip, knee and ankle (vertical line)

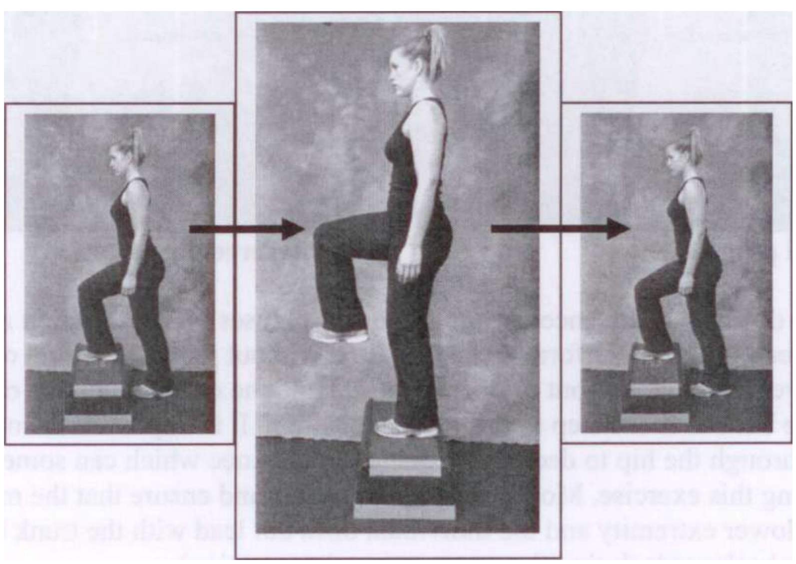


Frontal plane step up

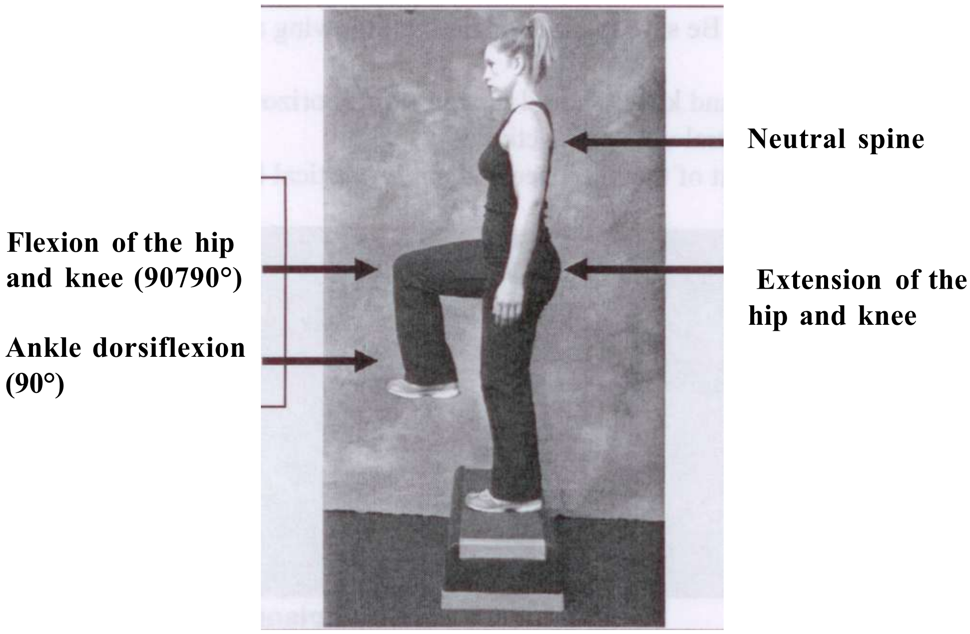


Transverse plane step up

The individual must demonstrate the ability to both master the basic version and stand in a unilateral stance without compensations before moving on to the following progression. The step up to unilateral stance is the next progression and is perhaps one of the most effective ways to train the extensor chain. Begin with the basic step up and procede into unilateral stance. See figure for the proper alignment at the end of the ascent. Be sure to ensure proper mechanics during deceleration (decent phase).

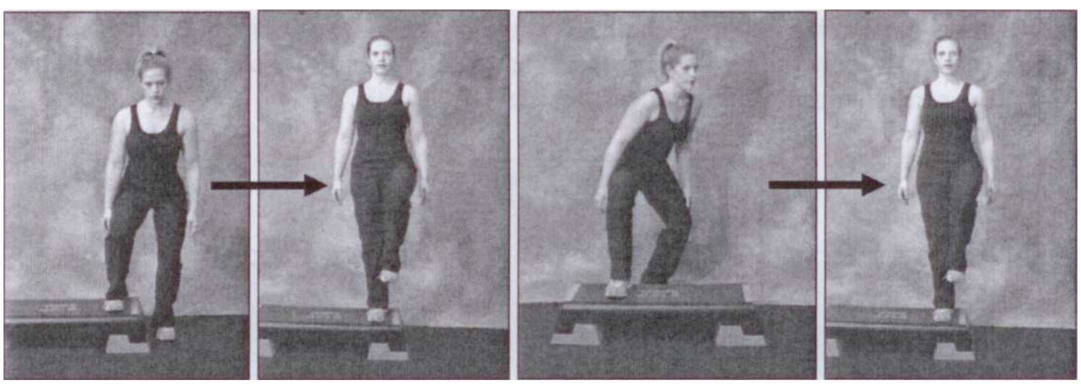


Step up to unilateral stance



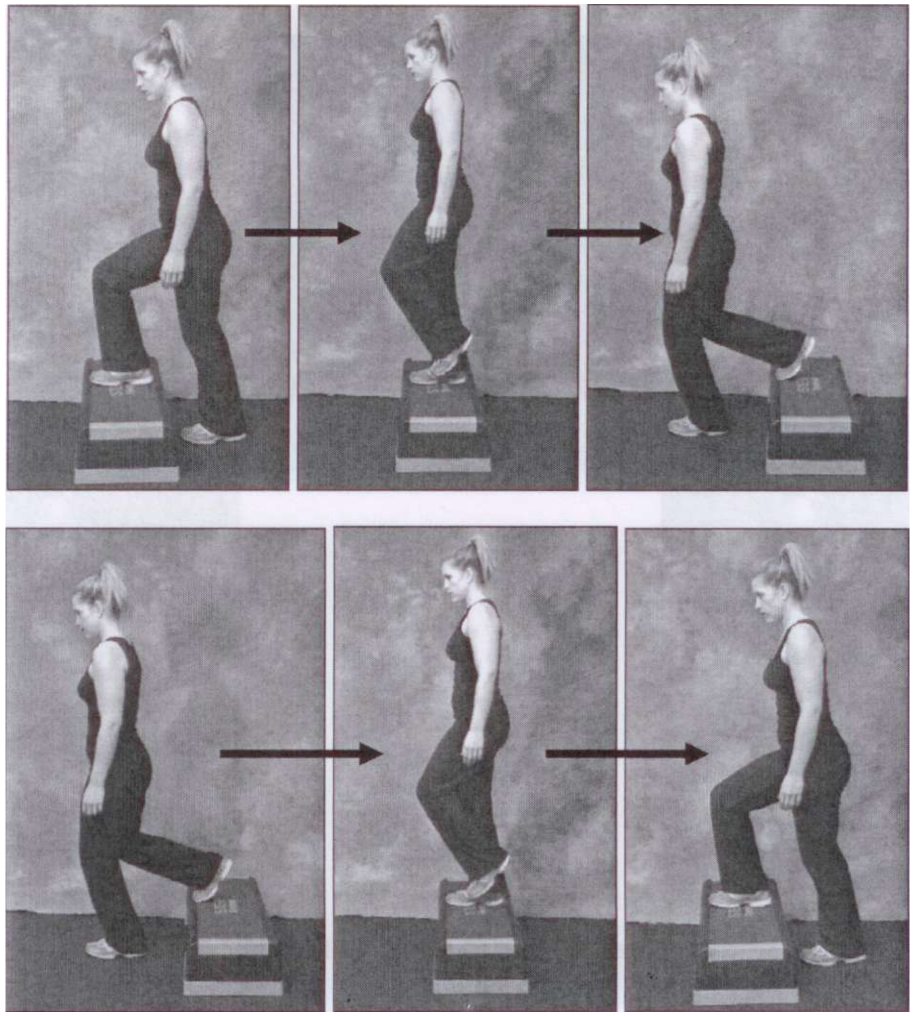
Proper alignment and mechanics during step up to unilateral stance

As with the basic version, the step up to unilateral stance can also be performed in the frontal and transverse planes.



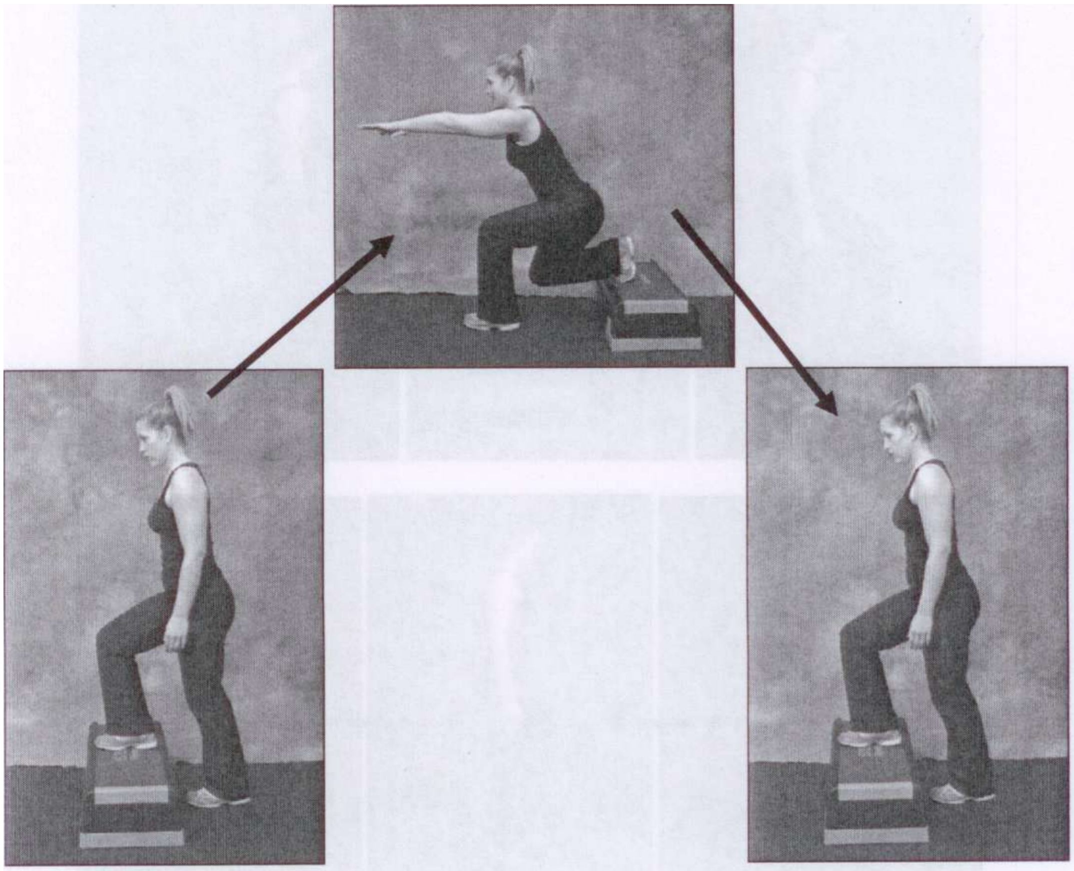
Step up- frontal plane **Step up- transverse plane**

The step up/step down is an advanced progression that focuses on deceleration mechanics of the entire lower extremity. Perform the step up and without placing the foot on the platform, step over land just in front of the platform. Hold the deceleration for one second and then explode back over the step to the starting position. It is important to ensure proper loading through the hip to decrease pressure on the knee which can sometimes be a complaint during this exercise. Monitor for neutral spine and ensure that the motion comes from the lower extremity and the individual does not lead with the trunk (seen as leaning the trunk backwards during the return to starting position).



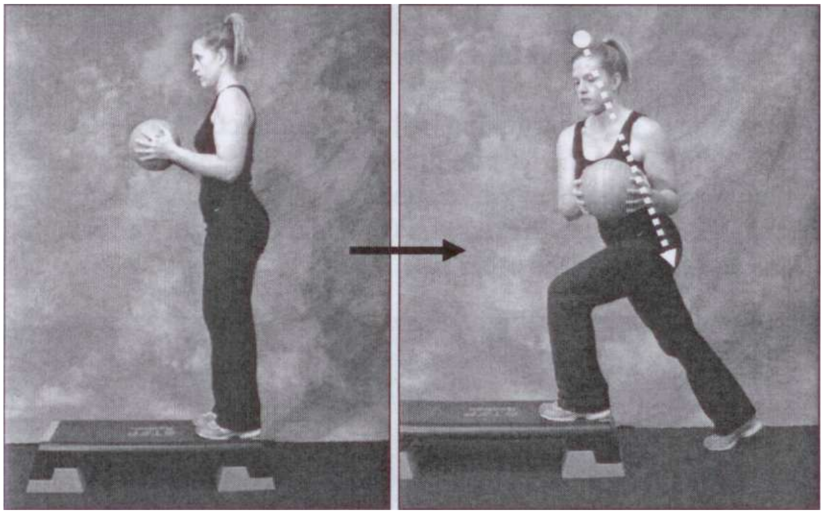
Basic step up/step down

For those individuals requiring a greater challenge, perform a deeper lunge at the end of the step up and over portion of the exercise. Ensure proper deceleration mechanics prior to returning to the beginning position.

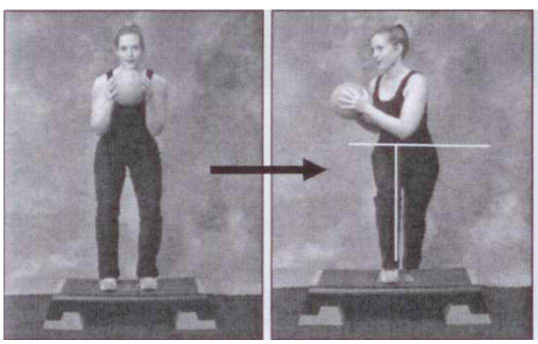


Step up to step down and lunge

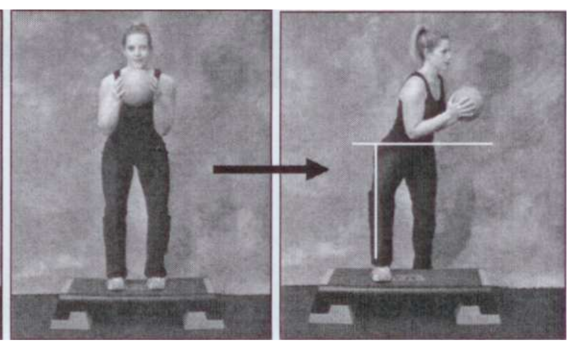
The step down with rotation is one method to improve hip rotation mechanics. Recall that nearly all sports and activities of daily living include some degree of hip rotation. The movement is performed by combining a step down with ipsilateral hip rotation (rotating towards the upper leg trains internal hip rotation). The hip rotation is created by moving the pelvis around a stationary lower extremity. Keep most of the weight of the upper body over the leg that is on the step (arrow). Maintain core activation and do not allow the lower extremity to deviate medially or laterally during the motion (white lines). The step down with contralateral hip rotation focuses on external hip rotation.



Step down with ipsilateral rotation (internal rotation)- lateral view

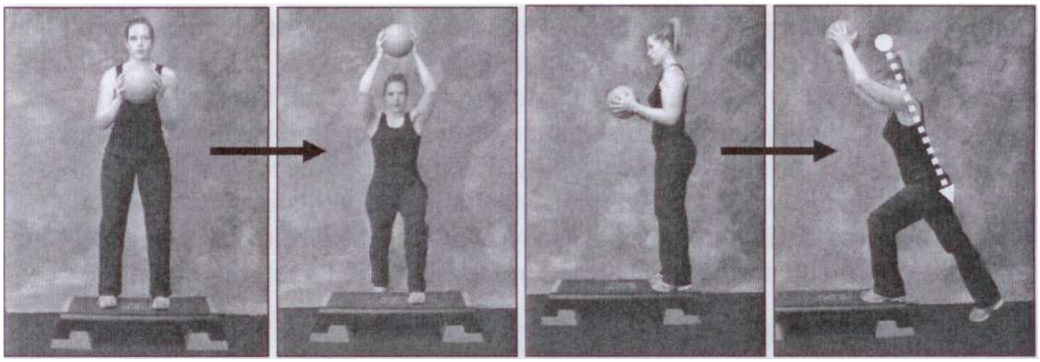


Step down with internal rotation



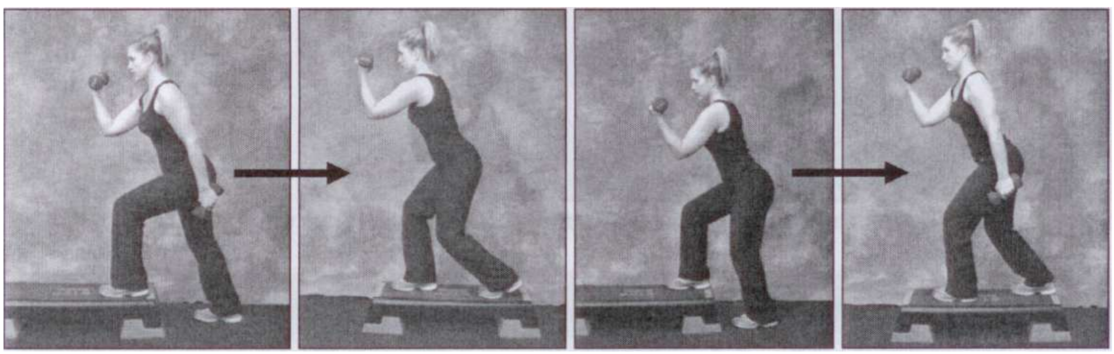
Step down with external rotation

The step down to overhead press is an extremely challenging exercise that targets the hip, core and shoulder complex. Because the arms are being pressed overhead as the body steps back, significant stress is placed on the core musculature to maintain the spine in a neutral position. Perform this exercise in the same manner as the above versions. Press the arms overhead simultaneously while stepping back. Maintain the weight over the leg that is on the step (arrow).



Step down to overhead press (front view) (lateral view)

The step up to curl is an alternative to stationary dumbbell curls and focuses on reciprocating arm-leg motion. Begin with one foot on the step and the contralateral (opposite side) arm in a flexed position. Step up while simultaneously curling the opposite arm and straightening the previously flexed arm (see image below). Perform the desired number of repetitions and repeat on the other side.



Step up to curl

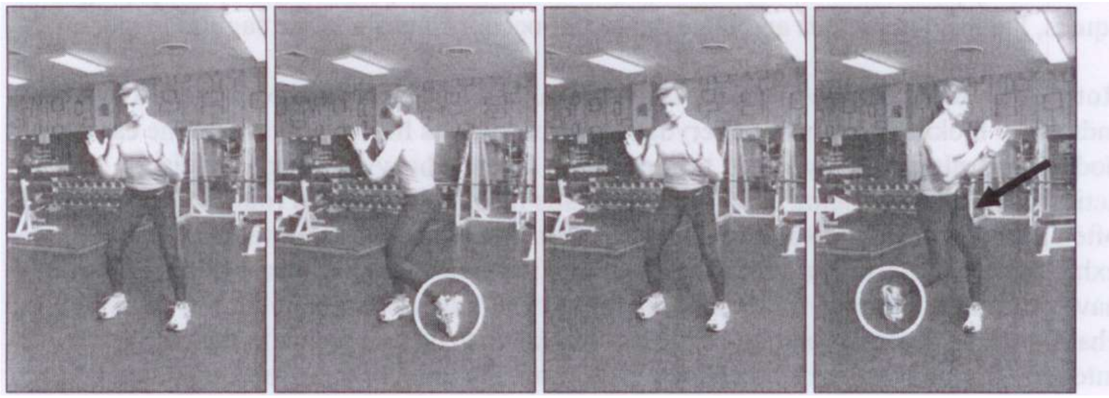
Rotation Patterns

Most muscles of the core are oriented in an oblique fashion. Why is that? As discussed earlier, it is to produce and control forces in the transverse plane, in other words, rotation. Virtually every motion that occurs within the human body requires rotation, especially ones involving motion of the lower extremities. And virtually every exercise that is traditionally performed for the core and lower extremities (i.e., crunches, sit ups, leg lifts, squats, lunges, leg presses and leg extensions) occur primarily in the sagittal plane.

Rotation patterns are one of the most functional exercises that can be performed by any individual looking to improve everyday function such as lifting a child into the car seat, dodging people on a busy street, turning while lifting a heavy package, or leisure activities such as swinging a golf club or tennis racquet. Decreased rotation of the hip is often a direct cause of disorders affecting the low back, pelvis and knees. Clients exhibiting over-activation of the deep external rotators of the hip ("butt grippers") will have diminished internal rotation of the hip. Recall that pronation of the lower kinetic chain includes internal rotation of the hip and knee. With a decrease in the obligatory internal rotation required to decelerate pronation, the low back and knee are especially vulnerable to the rotational and shear forces that are produced during activities such as lifting a heavy package and turning, perform a golf swing or with running.

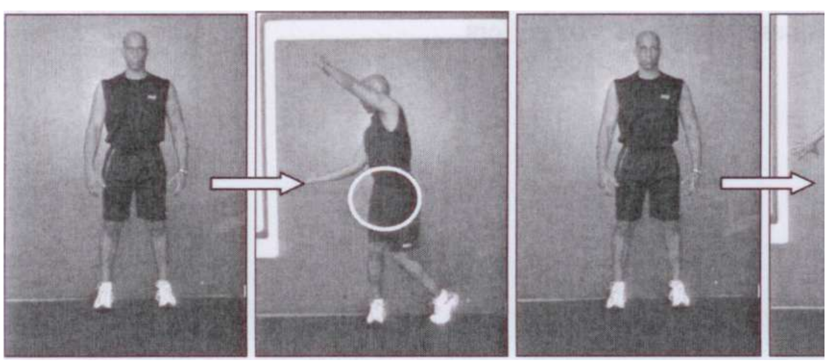
Rotation patterns are one way to develop the proper biomechanics and muscle force required to produce rotation of the hip while ensuring control of the core. The movement combines flexion, extension and rotation through multiple planes. The core muscles function not only to stabilize the core in an upright posture, but they also act to decelerate the momentum generated by the rotation of the trunk. Virtually all sports require the ability to dynamically rotate the hips with concurrent motion of the trunk and upper extremities. The rotation patterns target the hip rotators (tensor fascia latae, gluteus maximus/medius, piriformis and deep external rotators) and are an excellent dynamic warm up for individuals involved in racquet sports including tennis or activities requiring dynamic rotation such as baseball pitchers or golfers.

- The progression begins with performing the pattern with bodyweight.
- Perform the movement only in the range of motion that is available to your client.
- Take care not to over-rotate the available motion of the hip (flexibility of the gluteus maximus, biceps femoris, piriformis and other deep hip rotators) since this increases the stress on the knee (black arrow).
- Be sure to pivot the foot of the trailing leg (circle) which decreases the torque forces through the knee.



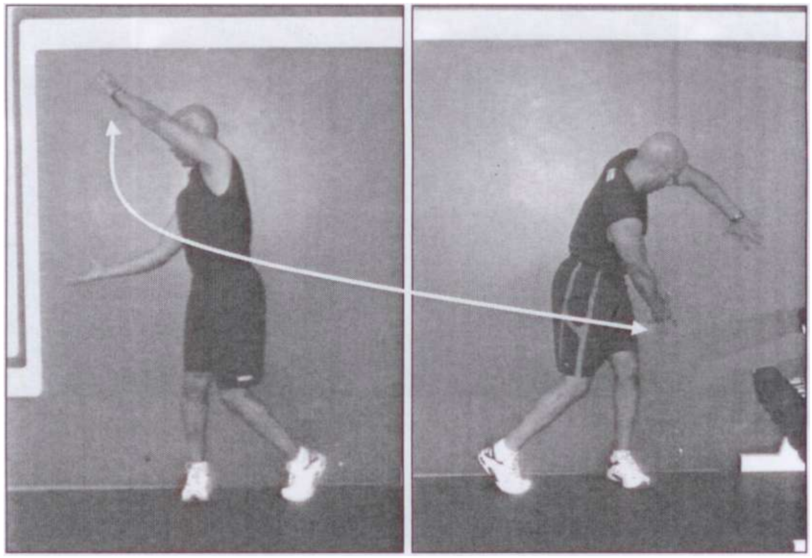
Rotations- basic pattern

While the following versions are performed with the back against a wall, they can performed in an open setting as well or loaded with a pair of light dumbbells. Begin with a neutral spine and core activation. Without moving the pivot leg, rotate to the right by reaching the outside arm overhead and the rear arm reaching back towards the wall. This pattern trains internal rotation (circle) and targets the decelerators of internal rotation (gluteus maximus, posterior fibers of gluteus medius and piriformis). Return back to neutral and repeat the pattern in the opposite direction. Next perform a similar hip rotation pattern by reaching the outside arm down next to the waist as it reaches back towards the wall. Repeat in the opposite direction.



Rotation with over reach **Rotation with under reach**

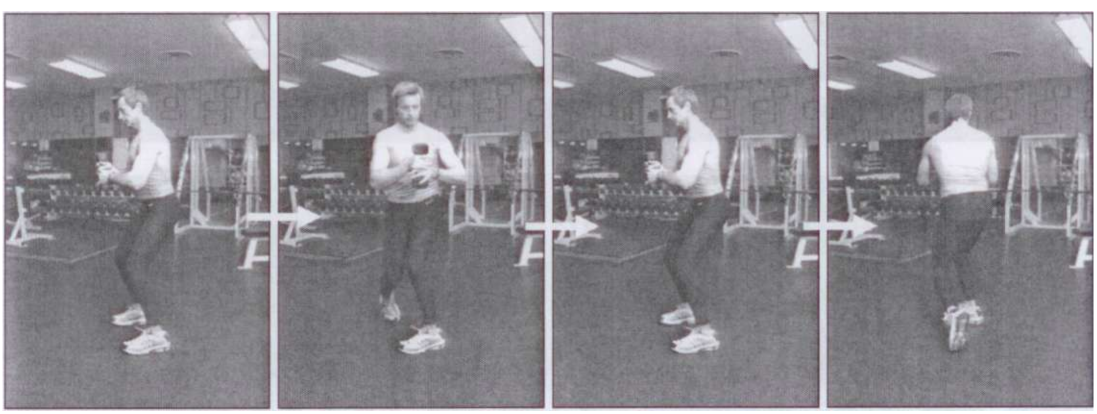
Combine both of the previous patterns to improve transitional mechanics After mastering the above versions, combine both patterns into one motion.



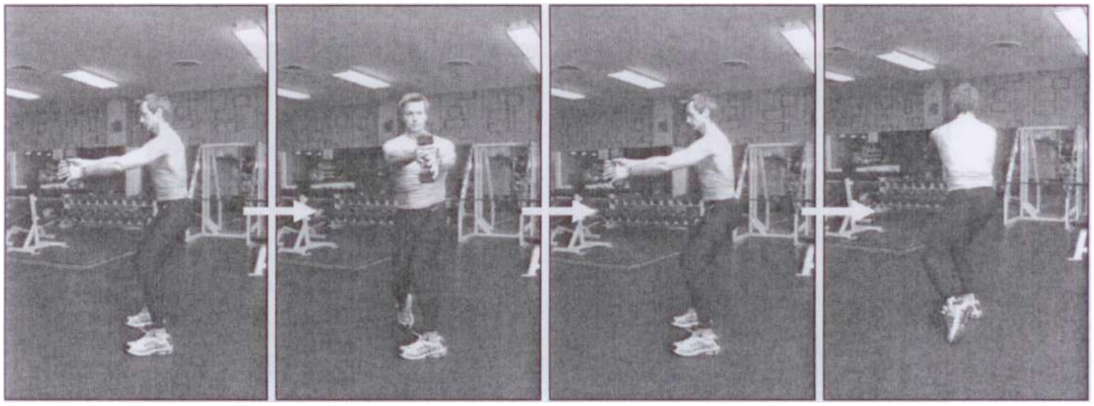
Rotation with combination over/under patterns

- Once the basic patterns have been mastered with bodyweight, increase the resistance by adding a dumbbell held closely to the body (tight rotations).
- Increasing the lever arm (wide rotations) adds additional demand particularly on the extensor chain of the core. Performing the movement with a cable, trains pure rotational motion since the resistance occurs perpendicular to the pull of gravity (white arrow) throughout the entire arc of motion.

Perform the cable rotations with tight form; core activation and stable lower body. Progress to performing the motion with hip rotation. Note that there is not excessive rotation of the trunk during the movement. Any of the previous patterns can be made more functional and challenging by increasing the speed of the pattern to more closely mimic the forces we deal with in real life or sporting activities.



Tight Rotations

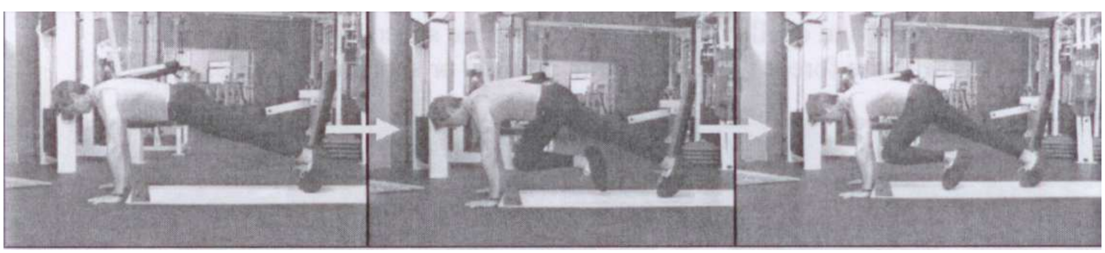


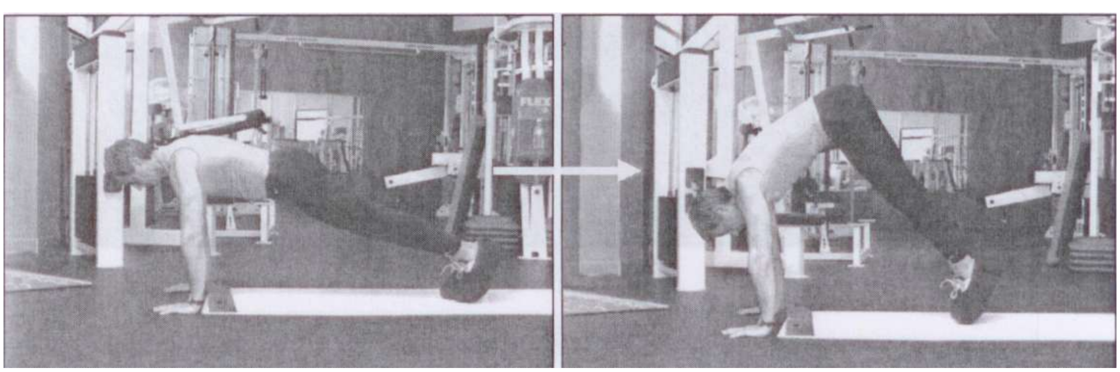
Wide Rotations

The Slide Board

The slide board requires excellent core control during motions of either the lower or upper extremities and is a great tool for training the entire kinetic chain.

- Begin the progression in the plank position and perform alternating hip flexion.
- This can be performed utilizing a slow tempo (one leg in, one leg out) or a continuous faster paced tempo replicating more of a running cadence.
- The pike slide follows the single leg version as this version requires tremendous core strength and stability.
- Be sure to maintain core activation throughout the movement and neutral spine throughout the movement.





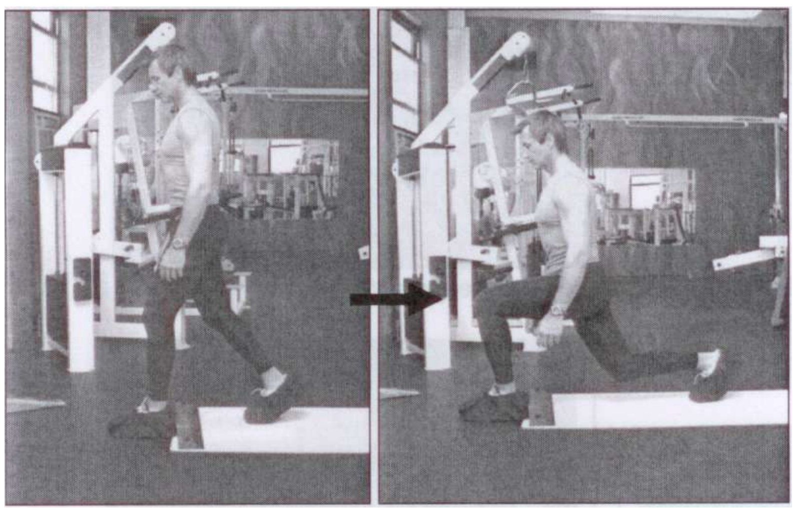
Slide Board Variations

Slide Board Lunge Patterns

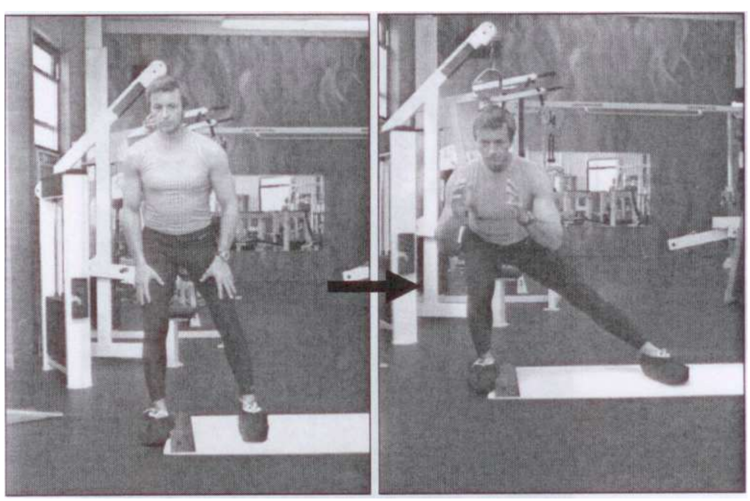
The basic slide board lunge can be performed in the sagittal and frontal planes. Begin with core activation and neutral pelvis and spine position. The motion begins by flexing through the hip of the stationary leg while the opposite leg is slid along the board. Monitor closely for proper form and loading through the hip.

The range of motion during any of the slide board lunges is determined by the following factors:

- the ability to maintain neutral spine and pelvis
- the available range of hip flexion of the forward leg
- the available length in the rectus femoris and hip flexors in the rear leg (sagittal plane version)
- the available length of the hip adductors in the sliding leg (frontal plane version)

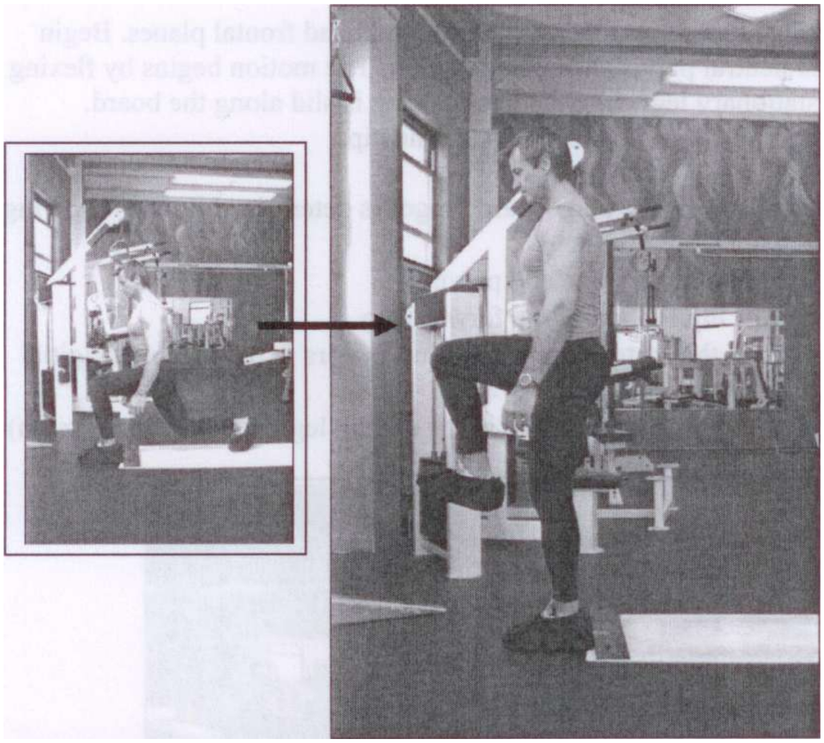


Sagittal plane slide board lunge

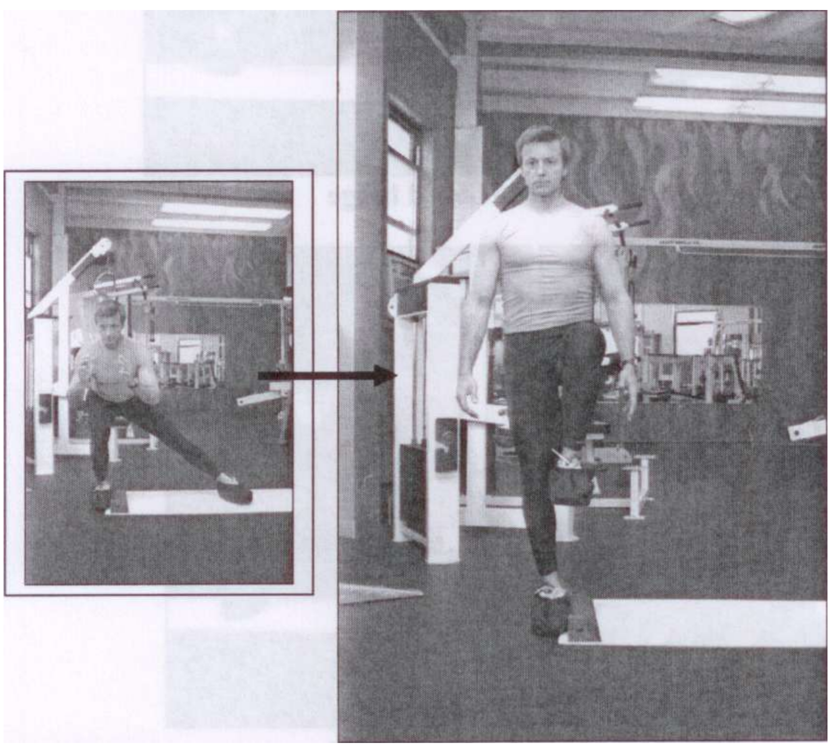


Frontal plane slide board lunge

Once the basic versions are mastered, progress to the unilateral versions

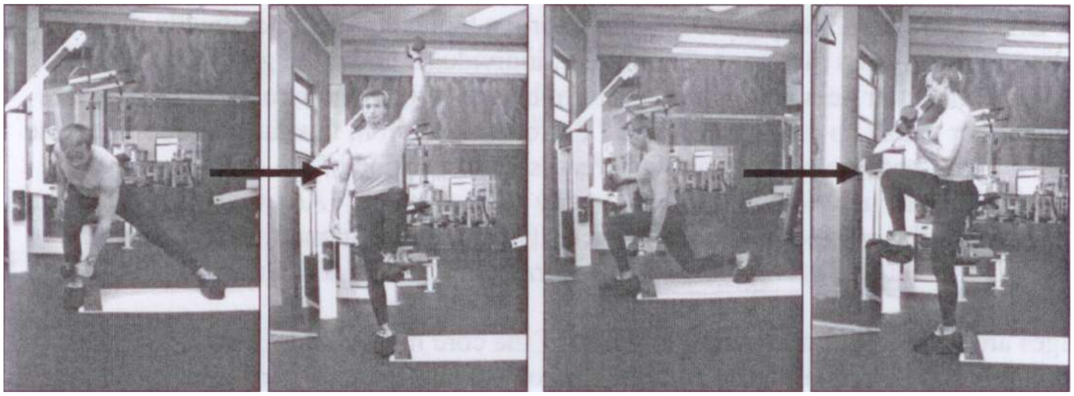


Slide board lunge to unilateral stance- sagittal plane



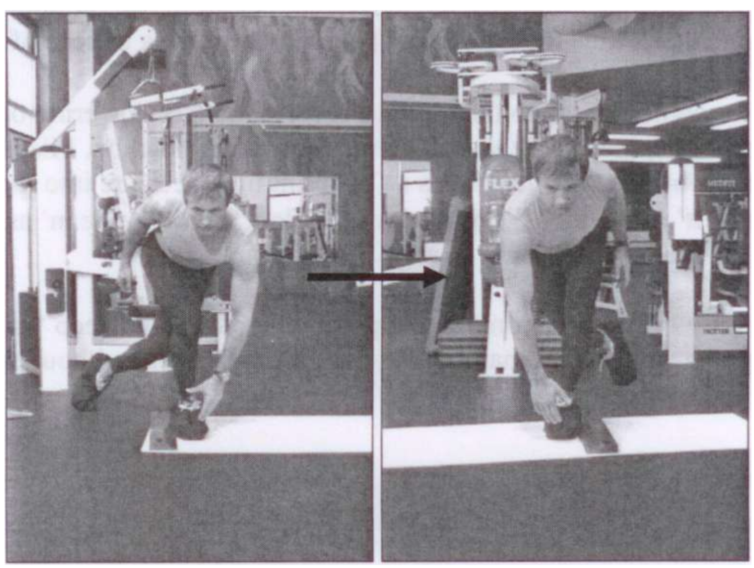
Slide board lunge to unilateral stance- frontal plane

Alternating limb patterns (pushing and curling) can also be performed to increase the demand and functional carry over of the pattern.



Slide board unilateral patterns

Skaters are an advanced way to train the entire core and lower extremity while improving each component of the movement continuum- acceleration, stabilization and deceleration. Due to the frontal plane of motion, this movement places significant demands on the lateral hip complex, in particular, the gluteus medius and tensor fascia latae. Begin at one end of the slide in a semi-squat position and arms held in front of the body. With a strong push off, slide the body to the opposite side of the board and decelerate the hip by lowering into a similar semi-squat. Repeat the pattern to the other side. Skaters can be performed for time or a desired number of repetitions. Adding a contralateral reach makes the movement pattern more sports specific for tennis players (reaching to return a volley) or baseball players (a fielder stretching out and reaching for a ball)



Skaters with contralateral reach

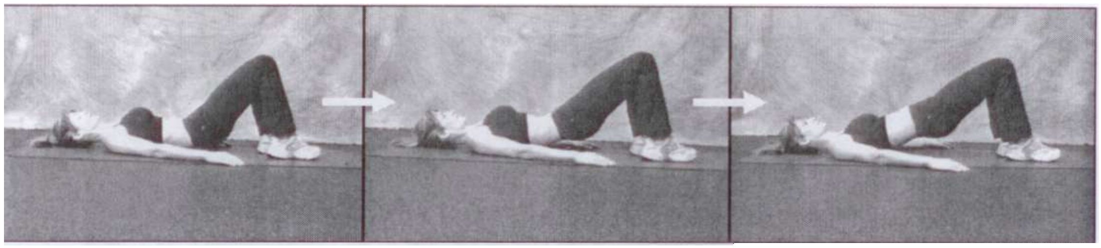
Bridges

Bridges are a popular exercise with individuals looking to "tone" the glutes and are routinely performed in rehabilitation settings for those experiencing low back and hip pain. Bridges are commonly performed to improve hip extension, specifically the function of the gluteus maximus. Commonly, individuals under the guidance of a physical therapist or personal trainer, perform bridges with the instructions to "squeeze the glutes" or "push up through the hips." Performing them in this fashion does increase gluteal activity but also preferentially increases the activation of the deep hip rotators, especially in those individuals who are already "butt grippers." Additionally, performing the exercise in this manner increases the activity of the lumbar and thoracic erector spinae, another muscle group that is often overactive in most individuals.

Bridges are utilized to improve the function of the core musculature, primarily the abdominals and hamstrings, and additionally to decrease the tone and increase the length of the deep hip rotators and erector spinae. This is an excellent exercise for those requiring decompression/relaxation of the spine (due to increased tonicity through the erectors), individuals with hip pain (due to over-compression by the deep hip rotators) and as a coordination movement for the core. The one-legged version can be performed after the basic version is mastered.

- The individual is given the cue to begin by activating the core and relax through the hips, spreading through the sit bones (ischial tuberosities).
- The hips and gluteals should remain relatively loose and relaxed throughout the motion.
- Next, the individual performs small range anterior and posterior pelvic tilts while ensuring relaxation of the hip rotators, gluteals and erectors.
- As the performance improves, the individual begins to roll the spine off the mat one segment at a time (spinal flexion), similar to peeling a piece of tape of the floor.
- Lower the spine back onto the mat in a reverse manner, lowering one segment at a time until the spine and pelvis is in a neutral resting position. Pilates and yoga instructors commonly refer to this as "imprinting" the spine into the floor.
- 'Breathe out' as the spine is rotated off the floor and 'breathe in' as the spine is rotated back onto the floor.

The individual rises off the floor only to the point where they can keep 'rolling' (spine flexion) through the spine while maintaining core activation and without over-activation of the gluteals and hip rotators.

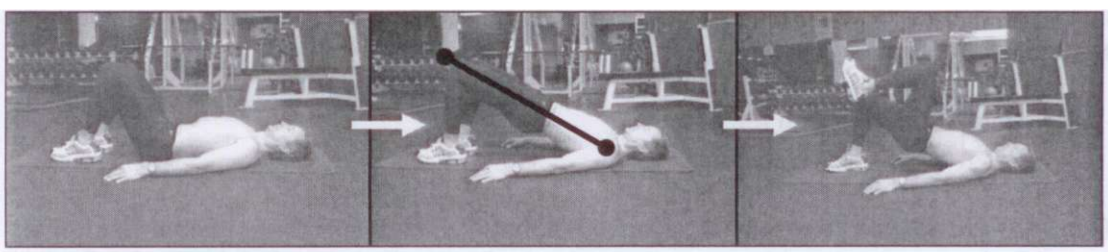


Bridges

The single-leg and marching versions, which increase the demand of the gluteus medius and core stabilizers, are performed after the basic version is mastered.

- Maintain neutral alignment between the shoulder and knee (black line).
- Ensure that the pelvis does not drop or shift as one leg is lifted off the floor.

Single-leg Bridges

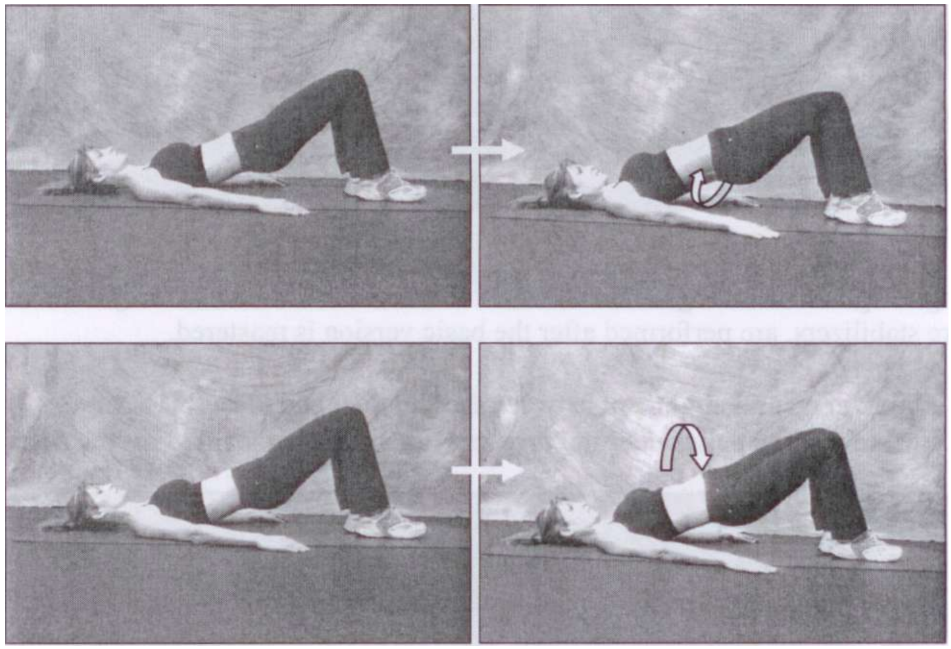


Marching-leg Bridges

The bridge with rotation is an excellent way to improve rotational flexibility in the spine and hips. Where as the seated spinal rotation movement creates rotation from a top down fashion, the supine version rotates the hip, pelvis and spine complex from the bottom up. Both versions are excellent movements for any individual who demonstrates restriction of hip and spine rotation and especially for athletes such as golfers and pitchers.

- Ensure core activation, relaxation through the hip rotators, gluteals and erectors as the pelvis is rotated.
- Breathe out as the pelvis is rotated.
- Breathe in as the pelvis is returned to neutral.
- Repeat in the other direction.

The feet should remain flat on the floor and the knees and thighs should remain parallel and stationary throughout the movement.

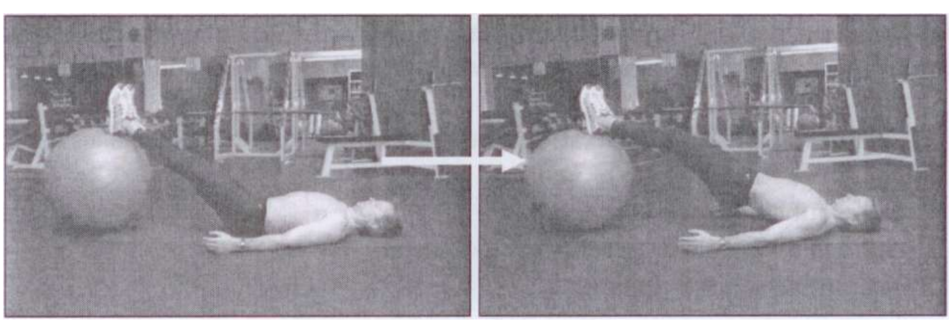


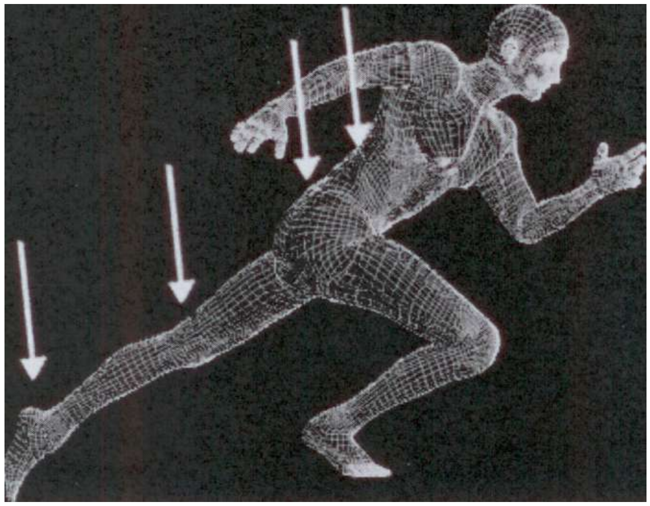
Bridges with Rotation

Once the floor-based version of the bridge is mastered, progress to the ball version. The bridge on the ball is an excellent move to train the entire extensor chain from the shoulders to the ankles and is especially effective in training the extension function of the hamstrings.

- Begin with heels on the ball.
- Progress to toes on the ball.

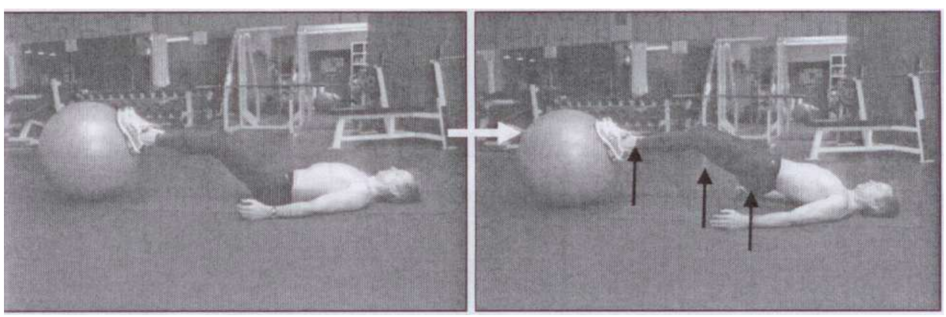
This adds the quadruple extension component that is vital in sprinting (plantar flexion at the ankle, knee extension, hip extension and spinal extension). The ball leg curl follows which increases the flexion demands of the hamstrings. Due to the increased stabilization demands of the core that the ball provides, care should be taken not to over-activate the deep hip external rotators and lumbar erector spinae.



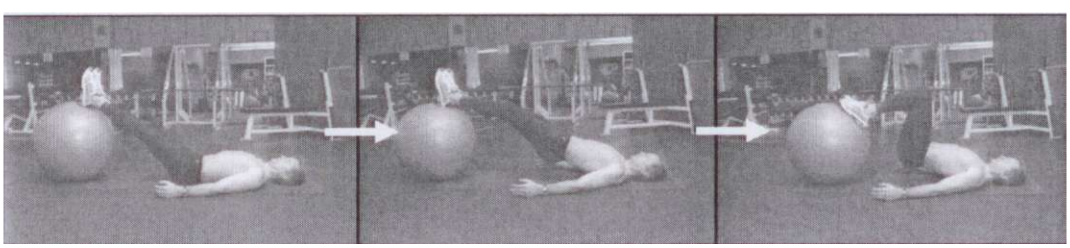


Triple extension: extension of the ankle, knee, hip and spine

Training triple extension functionally trains the entire extensor chain and represents a great conditioning tool for those individuals that experience chronic hamstring injuries. While knee flexion should rarely be trained in isolation, the ball leg curl adds a flexion component to the stabilization effect of the exercise progression.



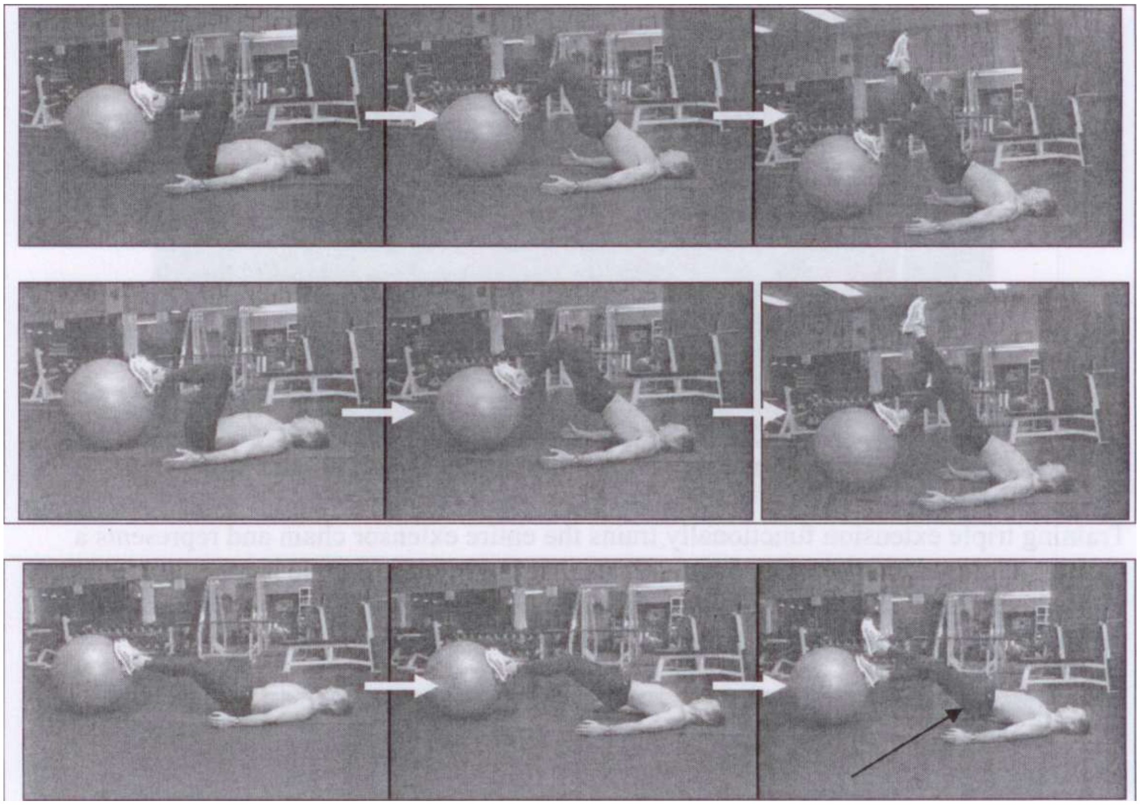
Jridge- toes on ball



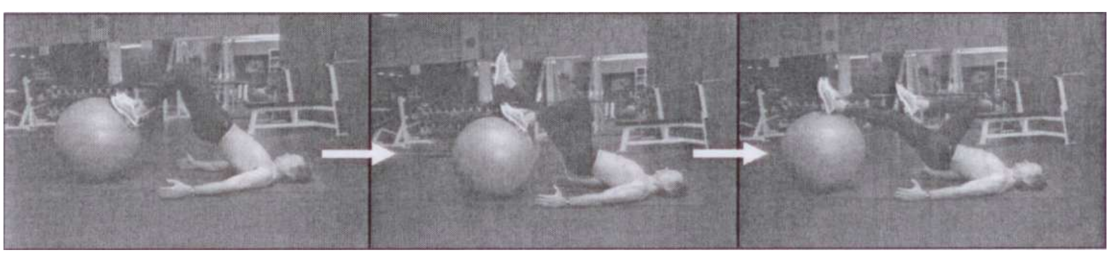
Bridge to hamstring curls

The single-leg lift-off and single-leg ball curl are advanced progressions that require high levels of core stability to maintain the pelvis and spine in a neutral or level position. They are incredibly functional since the mechanics are similar to the unilateral extension

patterns encountered during triple extension phase of sprinting (see above figures). The demands of this pattern makes it increasingly important to maintain a neutral pelvic and spine position in order to optimize force production and while minimizing the spinal rotational stresses as well as to the hips and sacroiliac joints.

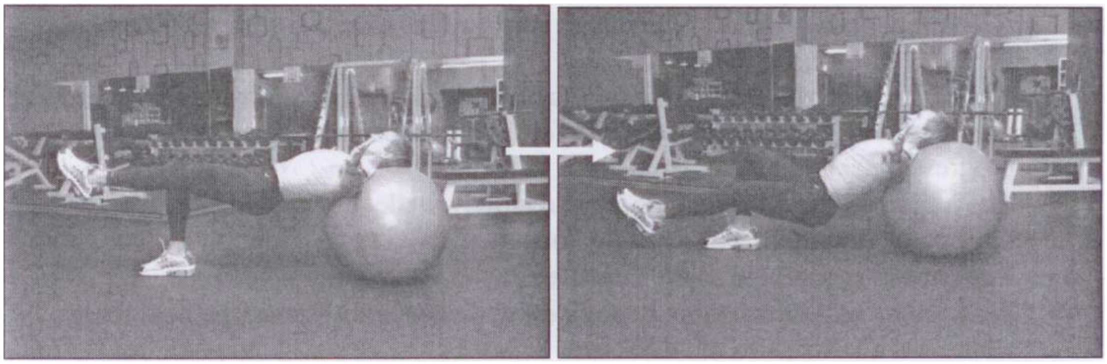


Single Leg Lift-off



Single Leg Curl

The single leg ball bridge requires exceptional core stability especially through the ground-based leg. Ensure a level pelvis and core activation throughout the movement. For individuals who demonstrate superior core stability and balance, resistance in the form or a dumbbell or cable as demonstrated below can be used.

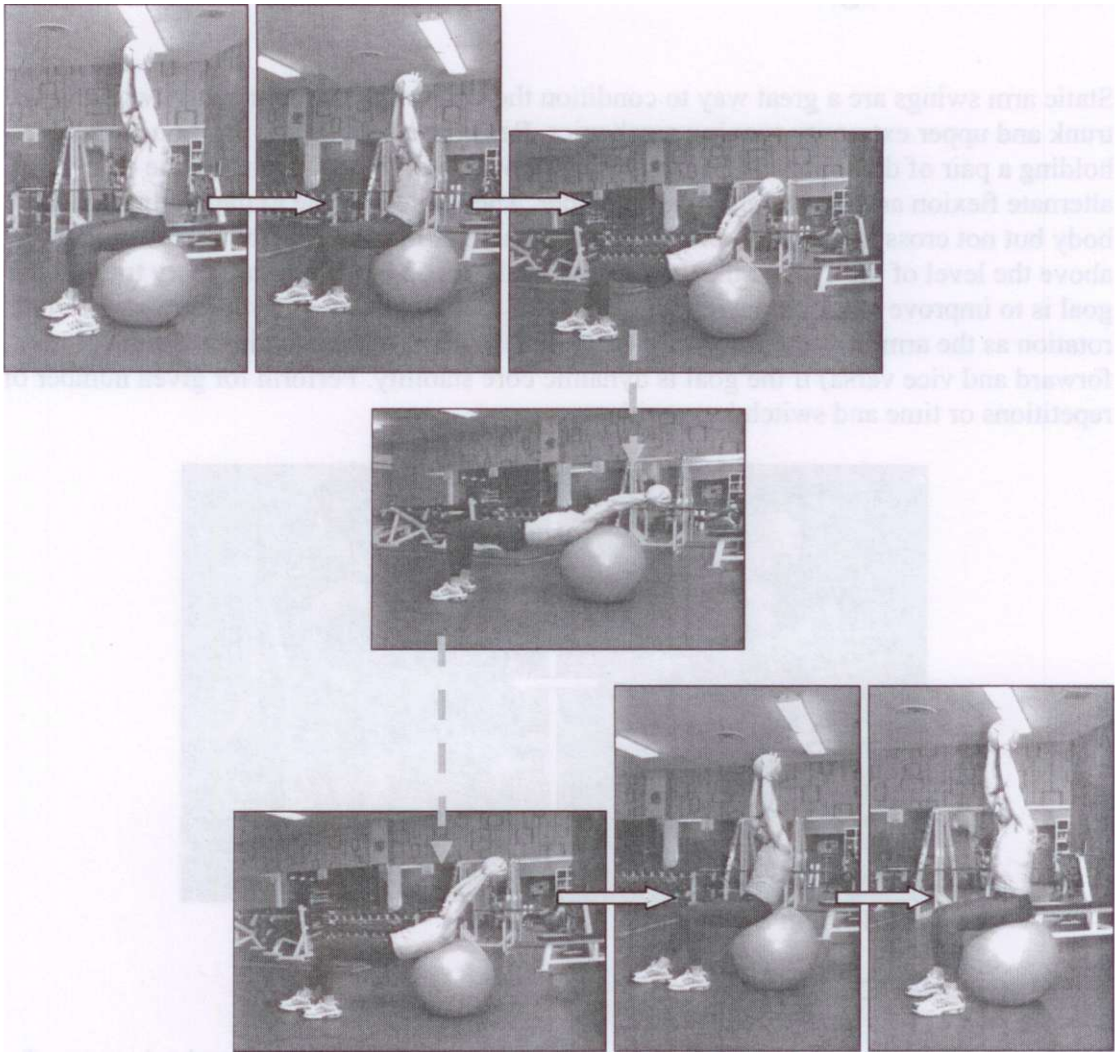


Single leg ball bridge with hip extension

Ball Walkouts

Ball walkouts are one of my favorite exercises for teaching core stability while incorporating lower limb mobility. The ball walkout is essentially a combination of a ball crunch and a supine bridge on the ball. They also serve as a way to progress a client from seated ball exercises to supine ball exercises. Even clients with back, hip and knee pain and rehabilitation/ post-surgical patients can perform this exercise with modifications.

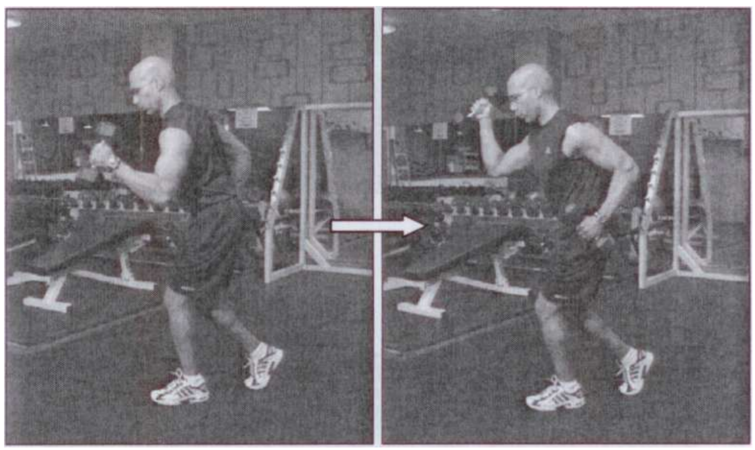
- The exercise begins with the individual sitting on the ball, core activated, arms at the side for beginners and overhead for those performing the advanced progression.
- The individual activates their core and slowly walks down the ball while curling their body around the ball until the torso is parallel to the floor.
- The pattern is reversed as the client returns to the starting position.
- A medicine ball (see figures below), dumbbell or body bar can be held for an additional challenge to the exercise.



Ball Walkouts

Static Arm Swings

Static arm swings are a great way to condition the core while simultaneously working on trunk and upper extremity running mechanics. Begin in a split stance position while holding a pair of dumbbells at 90 degrees of elbow bend. Without bending the elbow, alternate flexion and extension of the shoulder. The arm can come to the midline of the body but not cross it. The arm swing should be such as to not allow the hand to come above the level of the eyes or the too far behind the hip. Maintain a stationary trunk if the goal is to improve static core strength. Allow for a minimal amount of contralateral trunk rotation as the arm is brought forward (left trunk rotation when bringing the right arm forward and vice versa) if the goal is dynamic core stability. Perform for given number of repetitions or time and switch leg position.



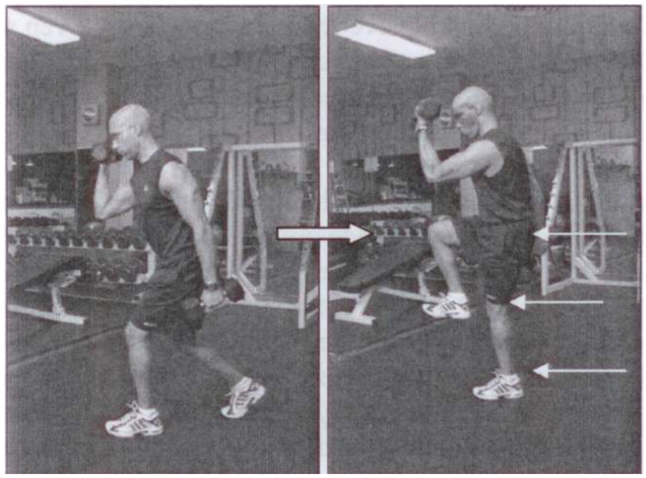
Static Arm Swings

Triple Extension Curls

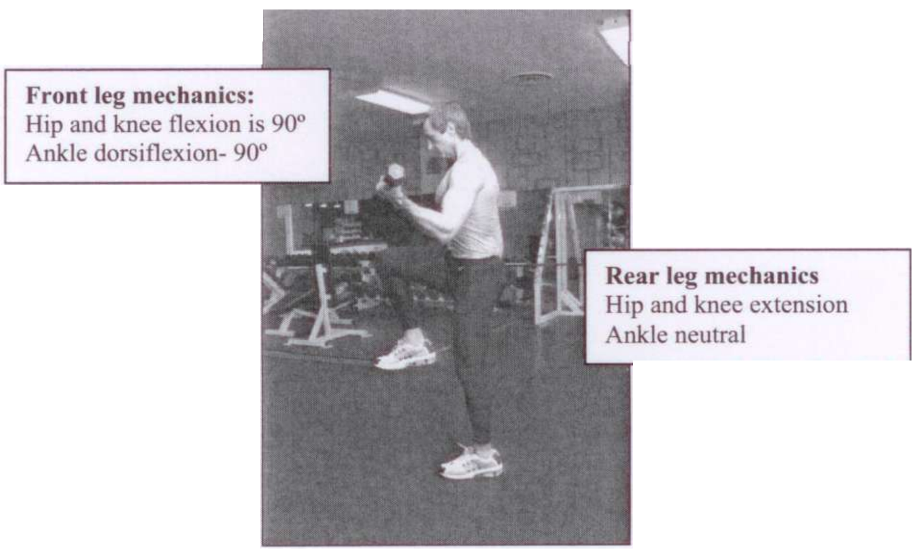
Triple extension (hip extension, knee extension, plantar flexion) is recognized as one of the most important components when training to improve speed. However, it is hard to mimic the mechanics of triple extension during many traditional exercises. While several Olympic lifts have a significant value in improving speed and power throughout the extensor chain, most of the exercises are not specific as triple extension occurs in a single leg stance. Triple extension curls (TEC) are one way to bridge the gap between Olympic lifting and field application. The can also serve as a great conditioning exercise in those individuals that have poor technique in the Olympic lifts or in locations where equipment is limited. Additionally, TEC can be utilized to improve the function of arm and trunk mechanics necessary for running and/or sprinting.

Begin in a split stance with the contralateral arm (arm opposite the side of the forward leg) bent to 90 degrees. The movement is initiated with simultaneous contralateral shoulder and hip flexion. Both the arm and shoulder should be brought to 90 degrees of flexion. Hold the position for one second to improve stabilization mechanics and

decelerate to the starting position. As the individual's mechanics improves, increase speed of execution. Be sure to monitor for both front leg and rear leg mechanics.



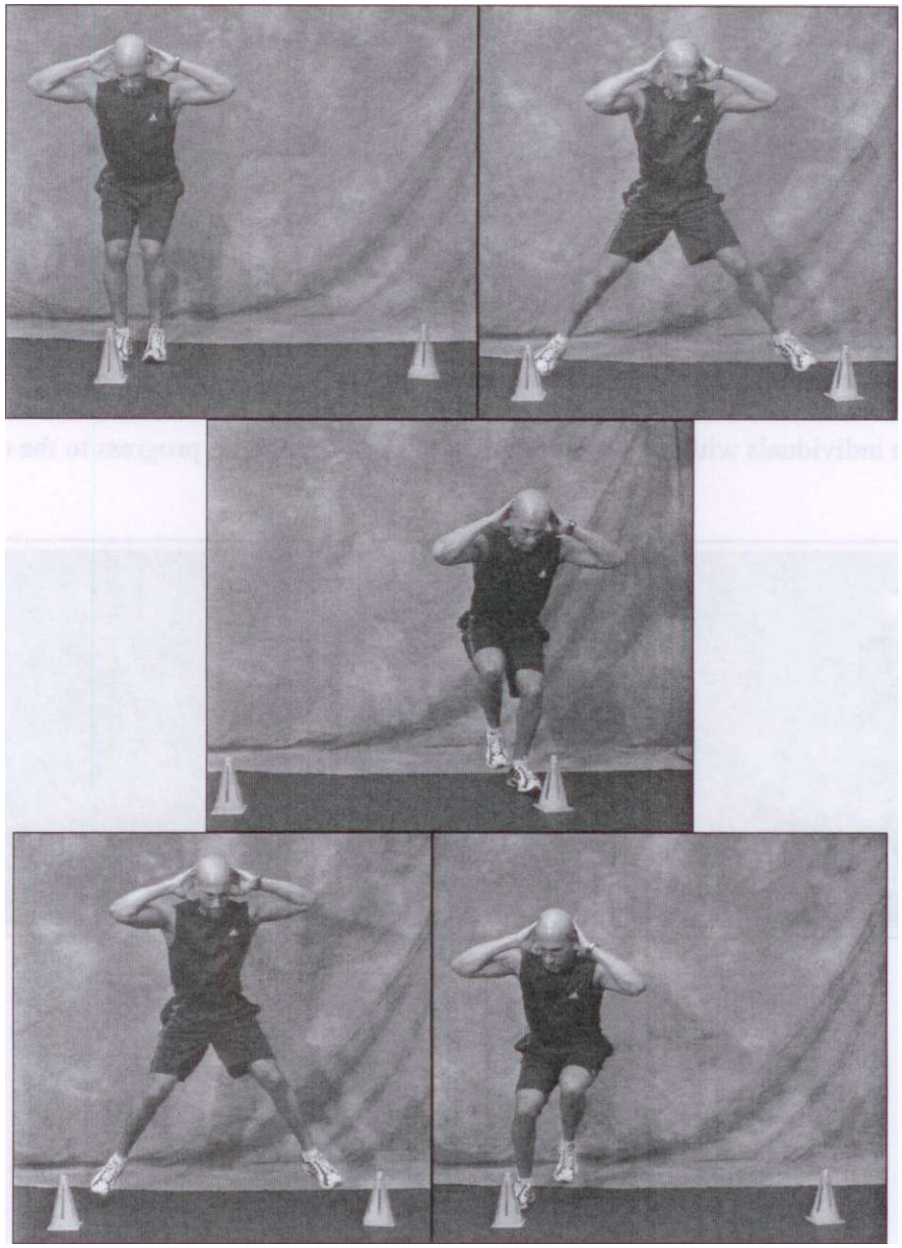
Triple extension curls



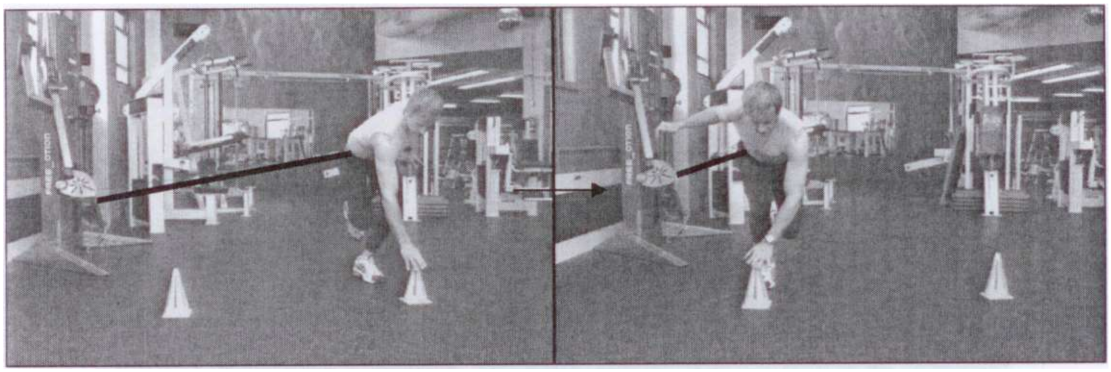
Lateral jumps

From the basketball player reacting to a drive in the lane, to the tennis player tracking a hard baseline shot or the cornerback in football tracking a receiver, most sports require the ability to move laterally with explosive force and precision. Even a slight loss of reaction speed can mean the difference between making a play and losing the advantage. Lateral jumps are one method to train the mechanics that are necessary to precisely accelerate and decelerate in a lateral direction.

Begin with the legs slightly closer than shoulder width and lower into a half squat position loading the extensor chain. Explode out of the position by pushing through the outside leg. Decelerate the momentum on the opposite leg and immediately accelerate back towards the starting position. Maintain the center of gravity (center of the body) within the base of support (plant leg)- allowing the center of gravity outside the base of support significantly diminishes the ability to decelerate the motion and apply force in the opposite direction. Perform for a series of repetitions or for time. Increasing the distance between the cones, adding a weight vest, performing the reps at a faster rate are all methods of progressing this exercise. Placing the hands behind back or behind the head diminishes the input of the upper body in the movement and focuses greater attention on the legs and core.

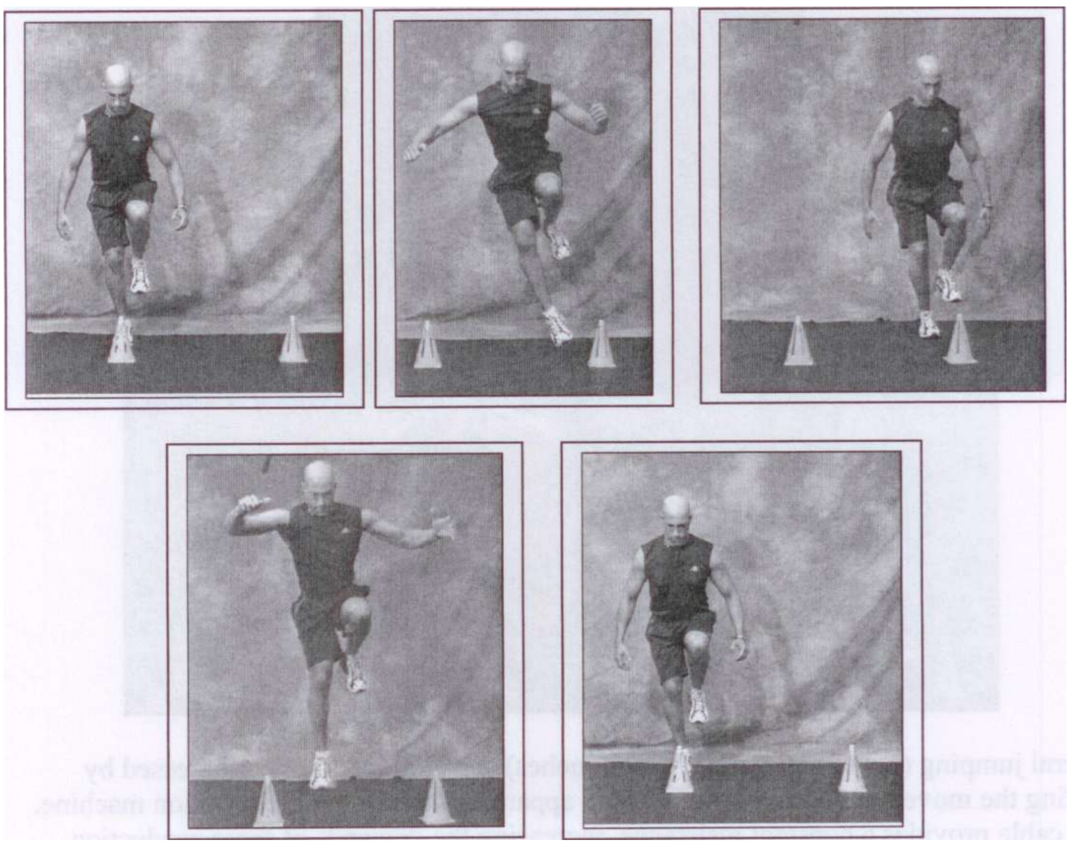


Lateral jumping (with contralateral cone touches) can additionally be progressed by loading the movement with a band or cable apparatus such as the Free Motion machine. The cable provides a constant resistance, increasing the demands of force production (acceleration) and reduction (deceleration) in the stabilization leg. Ensure proper biomechanics throughout the movement pattern.



Unilateral lateral jumps with cable resistance

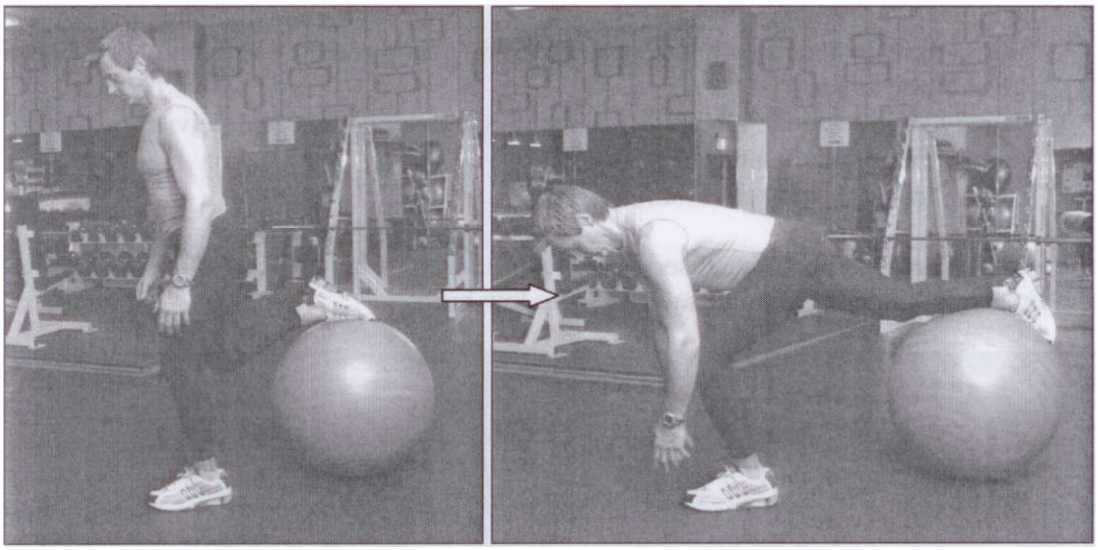
For those individuals with higher levels of stabilization strength, progress to the one leg version.



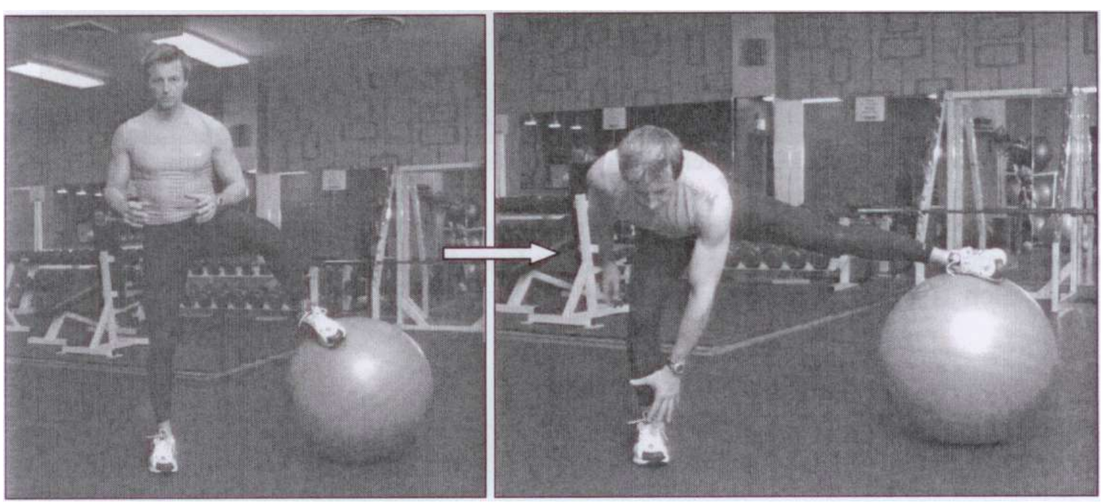
Unilateral lateral jumps

Single Leg Ball Slides

Single leg ball slides are excellent movement patterns in which to train hip mobility and stability in addition to deceleration mechanics of the extensor chain. Performing the hip extension ball slide pattern trains the hip in the saggital plane while the hip adduction/abduction pattern targets the hip in the frontal plane. Maintain neutral spine and core activation throughout the pattern.



Single leg ball slide- sagittal plane



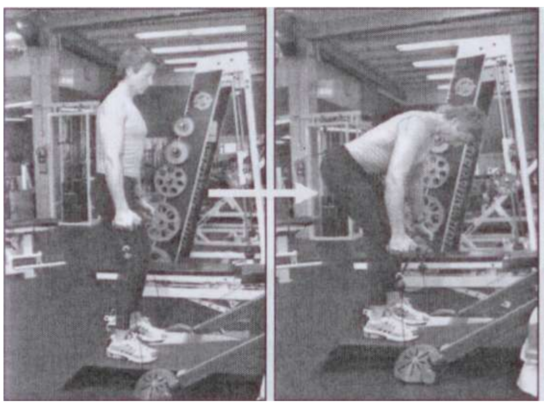
Single leg ball slide- frontal plane

Deadlifts

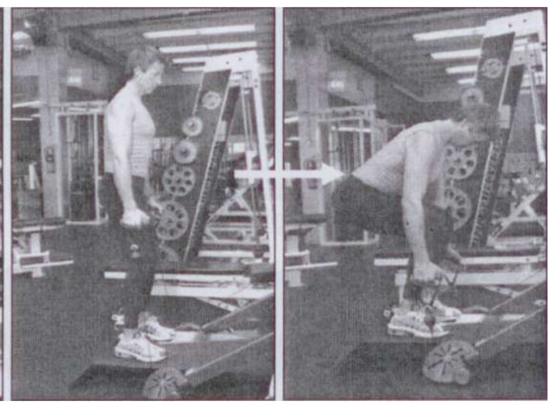
Along with squats, deadlifts are one of the oldest and most effective exercises for total body training. The entire extensor chain from the ankle to the head is engaged throughout this pattern. It is an extremely popular with Olympic lifters and power lifters and is a staple in many sports programs requiring significant strength, power and mass such as football, rugby and hockey. Deadlifts can be performed with barbells, dumbbells or cables, providing varied forms of resistance.

- Begin the movement with a neutral spine and pelvis and core activation and slight bend in the knees.
- Slowly bend from the hip while maintaining a neutral spine and pelvic position and the minimally bent knee position.
- Return to the starting position.

Performing the motion with increased knee flexion allows a higher load to be lifted while providing an increased margin of safety for the low back.



Romanian deadlifts with cable machine



Traditional deadlift with cable machine

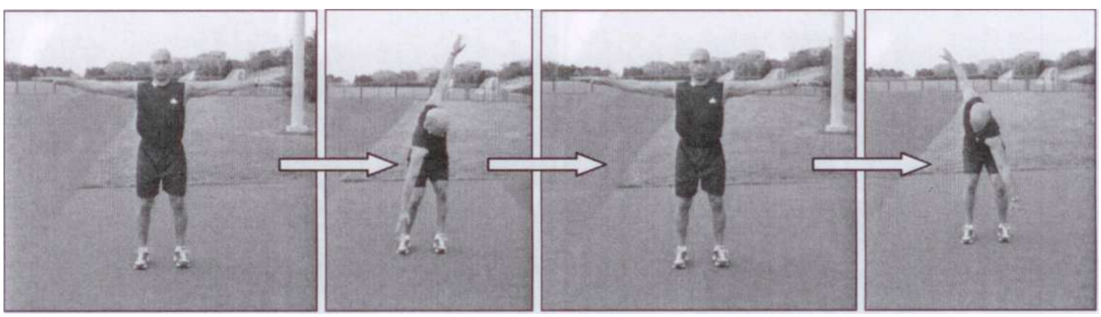
Progressions for the deadlift include performing them with asymmetrical loads (one cable or one dumbbell), while standing on one leg and one leg while standing on a labile surface such as an Airex pad or dynadisc.

Windmills

The windmill is one of the best all-around exercises to train balance, stability, coordination and flexibility of the core while improving hip function. Many activities of daily and sports require that the spine, pelvis and hips rotate in a variety of non-neutral postures, such as bending and twisting. The windmill is an excellent way to improve this function in a controlled environment, making it an ideal motion for golfers, pitchers and any athlete requiring rotational strength and stability.

- Begin with both legs straight, spine neutral, arms at 90° to the body and the core activated.
- Slowly rotate the trunk towards the side of the stationary leg which simultaneously trains internal rotation of the leg you are rotating towards and external rotation of the leg you are rotating away from.
- Return to the starting position and repeat to the opposite direction.

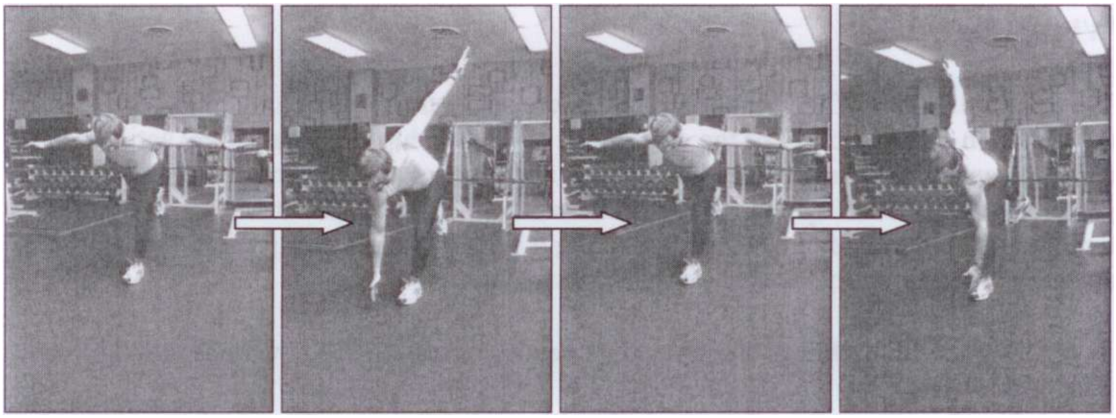
Both the pivot leg (side you are rotating towards) and the stabilization leg (side you are rotating away from) should remain stationary throughout the movement. The motion should occur at the hip only.



Windmills

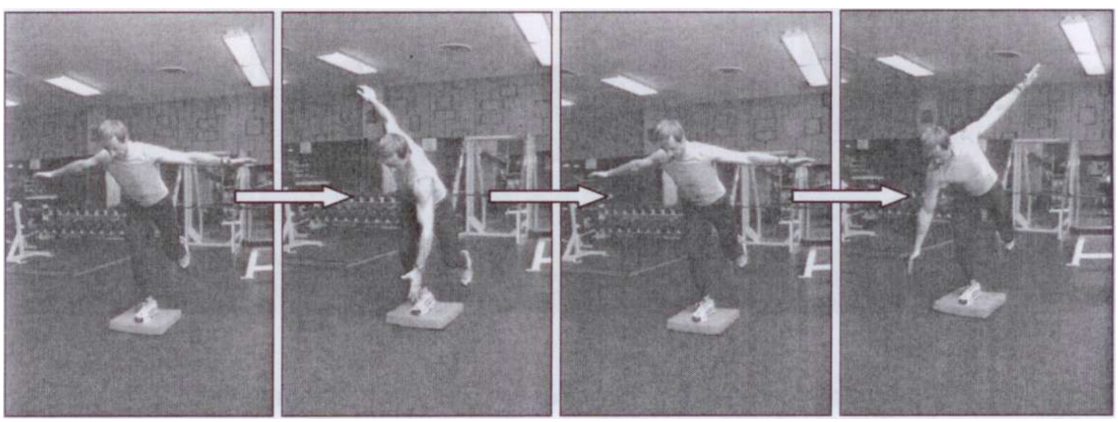
Performing the movement on one leg increases the stabilization demands of the exercise and increases the deceleration force required as the trunk and pelvis are rotated around the stationary leg.

- Begin by rotating the trunk towards the side of the forward leg. This targets the stabilizers and decelerators of hip internal rotation including the gluteus maximus and piriformis.
- The more difficult version requires trunk rotation away from the side of the forward leg targeting the stabilizers and decelerators of hip external rotation, including the anterior fibers of gluteus medius and tensor fascia latae.

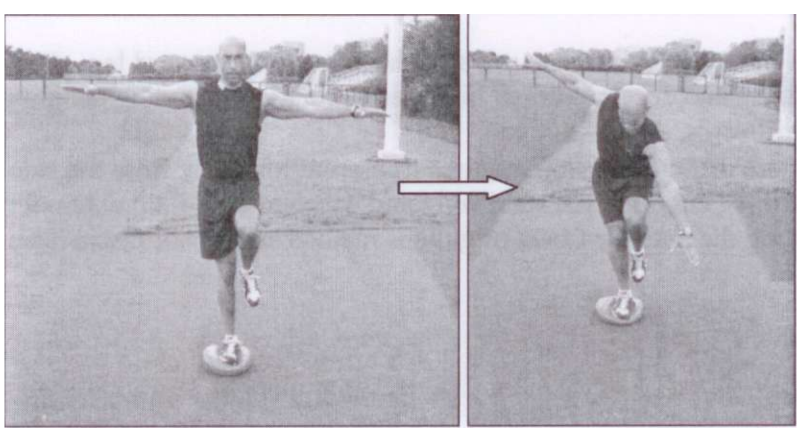


Windmills- unilateral stance

Performing the pattern while standing on a balance pad, disc or other piece of balance equipment increases the proprioceptive challenge to the core. It serves as an effective progression in which to condition higher functioning individuals that require extreme coordination and/or motor skill of the core and entire lower leg complex including soccer, volleyball, field hockey, football and basketball athletes. Ensure proper alignment of the ankle, knee and hip while performing rotation of the hip.



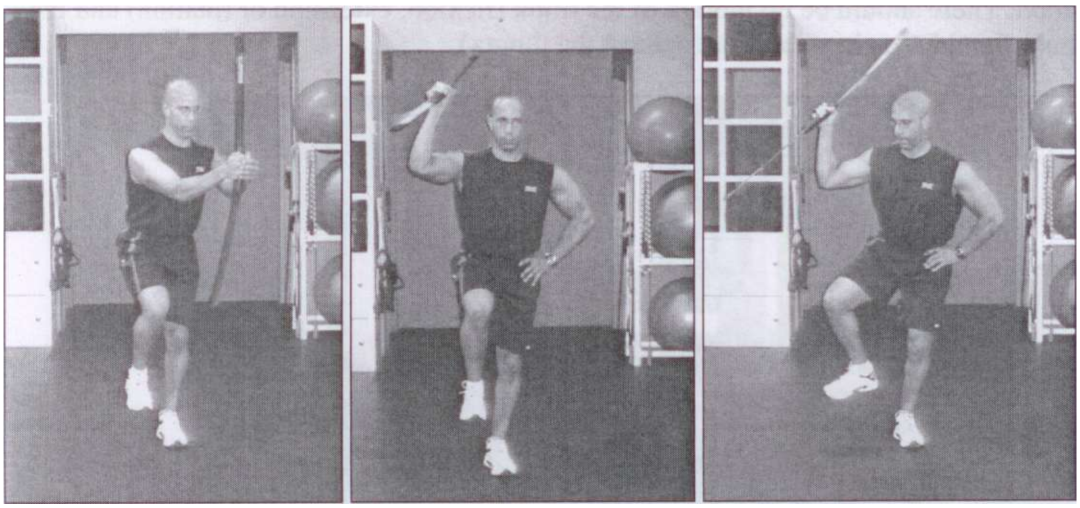
Windmills- unilateral on stability pad



Windmills- unilateral stance on dynadisc

Body Blade

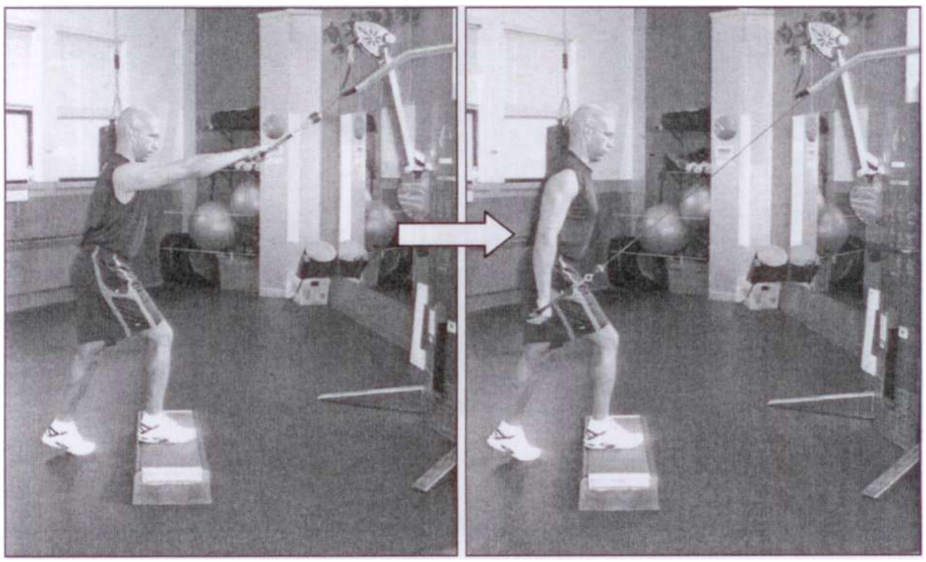
The body blade is a wonderful tool in which to train stability of the trunk and entire upper extremity in addition to the hip complex if performed unilaterally. The joint stabilizers are stimulated by the oscillation of the blade. Begin with a double grip on the body blade and move it back and forth using only minimal trunk or shoulder motion. Progress to performing the pattern with a unilateral grip and while standing on one leg. Rotating the arm, trunk and/or hip improves multi-planar stability and control.



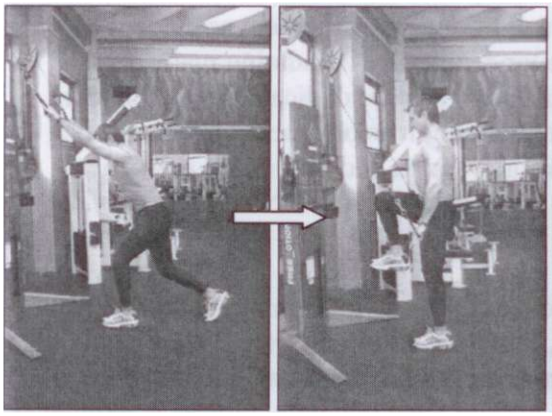
Body blade- variations

Cable Pulldown Series

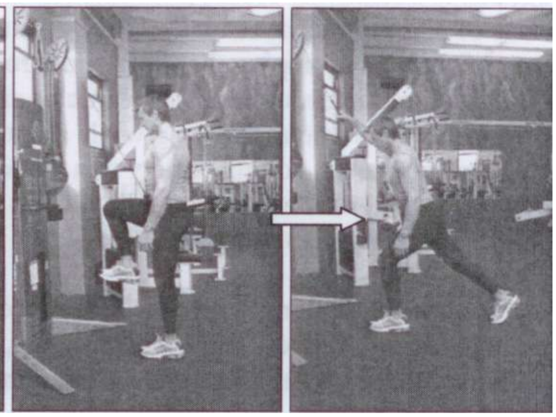
The cable pulldown series is one of my favorite progressions for training trunk stabilization combined with limb motion. One additional benefit of this exercise is the specific targeting it provides for the posterior oblique chain (latissimus dorsi, thoracolumbar fascia and contralateral gluteus maximus). The series begins in a split stance with one leg forward (in order to tense the contralateral thoracolumbar fascia and gluteus maximus) with about 60% of the weight on the leg that is on the step. Grasp the cable with the elbow straight until the arm is about level with the floor. Activate the core and pull the arm to the side of the body. Hold for a second and return to the beginning position. There should be no motion of the trunk (flexion, extension or rotation) and the scapula should remain stable (flat against the thorax).



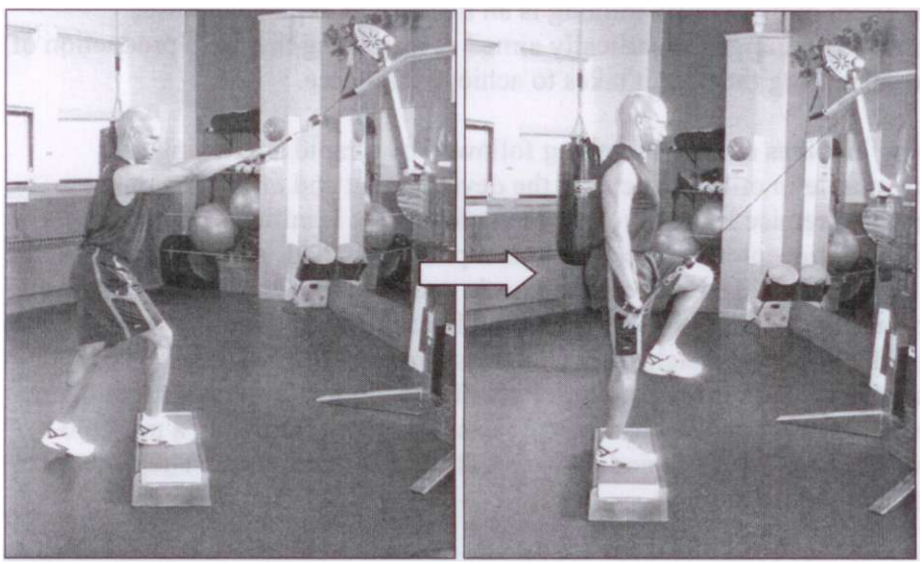
To increase the functional integration of this pattern, progress to the cable pulldown to unilateral stance. As with the previous pattern, ensure stability through the trunk and shoulder girdle and focus on triple extension of the stance limb and 90-90-90 degree flexion of the opposite limb.



Cable pulldowns- bilateral



Cable pulldown- unilateral



Cable pulldown with step up

Plyometrics

While plyometrics is not a new concept (originally used to improve the athletic ability of Olympic athletes in the early 1900's), the use of it as a modality in general training programs is a relatively recent phenomena. In fact, there has been a dramatic increase in the use of plyometrics in virtually every gym and training environment as evidenced by the proliferation of jumping, hopping and throwing currently inundating many individuals' training routines. Many articles and seminars are dedicated to expounding the benefits of plyometric training while recommending it as one method of increasing athletic performance, adding variety to a workout program and improving aesthetics (body composition). This section will address some of the current concepts, myths and applications of plyometric training.

The requirement of many sports activities is to exert the maximal amount of force in the minimal amount of time. The baseball swing, throwing a football, returning a tennis serve or sprinting off the line during a track meet all require maximal, explosive force production over a very short period of time to initiate the movement. Power is defined as "the rate at which work gets done" or the maximum force that can be generated per given time. The overall effect of plyometric training is an increase in explosive power production. Plyometric training is specifically aimed at increasing the force production of the muscle while decreasing the time it takes to achieve that force.

Plyometric training involves a rapid stretching followed by a rapid shortening or contraction of the muscle in order to increase the development and efficiency of explosive power. The premise is the myotatic or stretch reflex is initiated in the muscle spindles and other proprioceptors as the muscle is rapidly stretched. A signal is sent to the nervous system there is a rapid stretch on the muscle and in response the nervous system sends a message back to the muscle to contract rapidly to protect the muscle from the potential damage of being overstretched. This is the same response a physician is checking for when he/she strikes the patellar or achilles tendon with the reflex hammer. Simply, plyometrics is based on the premise the faster and more forcefully a musculo-tendinous unit is stretched, the faster and more forcefully it will contract. There are three distinct phases of plyometric training.

THREE PHASES OF PLYOMETRIC TRAINING

- **Lengthening (eccentric) phase**
- **Amortization phase**
- **Shortening (concentric) phase**

The eccentric, or lengthening, phase, takes advantage of the elastic properties of the muscles. During this phase, the muscles are pre-stretched to store elastic energy within the muscle. The amortization phase is the transition period from the eccentric phase of the motion to the concentric phase. The final phase is the concentric or shortening phase of the movement. The elastic energy stored within the muscle increases the force of contraction during this phase. While the obvious goal of plyometric training is to improve all phases, improvement in the amortization phase, or the time it takes to transition from

the eccentric contraction to the concentric contraction is the phase with the most application for the athletic population. It has been thought the fastest athletes are those individuals with the shortest amortization phase - the greatest amount of elastic energy the muscle is able to generate along with the shortest amount of time taken to use that energy.

While plyometrics has been shown to be an extremely effective training tool, basic conditioning is required prior to its introduction into a training routine. First, the individual must possess basic strength and stability. It has been suggested the individual be able to squat 1.5 to 2 times body weight, be able to move their bodyweight dynamically through multiple planes of motion and have enough cardiovascular endurance to handle one to several minutes of continuous exercise prior to beginning a plyometrics program (Radcliffe and Farentinos). Other factors necessary include adequate dynamic ranges of motion through all joint structures (dynamic flexibility), proper overall posture especially of the spine and pelvis and generally high level of overall joint stability.

Plyometric exercises for the lower extremities include jumps, hops, leaps and bounds while explosive push ups and medicine ball throws are often used to train the core and upper extremities.

It is often suggested that rather than performing plyometric exercises, we can simply perform our weight training exercises at a faster rate. However, if we analyze most sport type activities, we will find most of them require accelerated force production through the entire movement until the point of contact (bat striking the ball) or the release of an object (ball leaving the hand). During a baseball throw for example, the arm is accelerated until the ball leaves the hand. During weight training however, no matter how fast the weight is accelerated, it must be decelerated at the end of the movement in order to minimize injury. Therefore, traditional weight training is limited in its ability to generate maximal power output. However, by combining traditional weight training, with plyometric training, high levels of maximum strength and power output can be achieved.

Plyometric training recently received negative press primarily as a result of the advocates for the "superslow method" of training. The negative press surrounding plyometrics originate with improper use and application of plyometrics, not necessarily something inherently wrong with the exercise itself. Individuals who attempt plyometric training without an adequate basis of strength and stability increase their risk of developing injuries. Plyometric exercises are safe when applied appropriately. The basis of any method of training is to increase performance, whether it be life or sports. The effectiveness of a training program is determined by the ability to improve on the skills that most closely resemble the activity the individual is training for. Does life or sports ever occur at super slow speeds? We all know the answer is a resounding NO. If you are going to participate in activities requiring explosive generation and reduction of forces in addition to rapid changes in direction, you must adequately train for them. After all, isn't what children do everyday of their lives (jumping, running, hopping, skipping, throwing)

just plyometric training cleverly disguised as playing? With that being said, follow the proper progressions to help ensure the plyometric exercise program is being used in a safe and effective manner.

PROGRESSIONS FOR PLYOMETRIC TRAINING

Ensure plyometric training is appropriate for the client
Not every client needs or will benefit from plyometric training. Remember, plyometric training is maximal force generation. This type of training is not appropriate for most seniors, adolescents or those with poor core strength, movement patterns or injuries. High performance athletes (college, professional and Olympic) are sometimes the exception to this rule since they often need to perform at a high level despite dysfunctional movement patterns and injuries. However, their conditioning program should focus on restoring proper core stabilization and proper movement patterns prior to initiating or performing plyometrics.

Establish a baseline of core strength and stability
The core is the basis of all movement and therefore the emphasis should be on establishing adequate core strength, endurance and coordination with the extremities. When the individual demonstrates adequate core strength in multiple planes in addition to the guidelines outlined above, a plyometric program can be instituted.

Ensure the individual can perform multi-planar movement patterns with no movement faults or pain
If an individual demonstrates movement dysfunctions and/or pain, they will exacerbate these conditions due to the high level or performance required with plyometric training.

Follow the proper progressions of functional training with continual monitoring
As with any training program, following the proper progressions will dramatically decrease the likelihood of injuries. Adherence to the proper progressions gives the individual the base level of strength, coordination and skills to succeed at plyometric training. Due to the high levels of force generated, proper form and technique must be adhered to and monitored in all individuals during training. Pay special attention to the eccentric and amortization phases as these are the points during which most individuals tend to break down.

Progressions include:

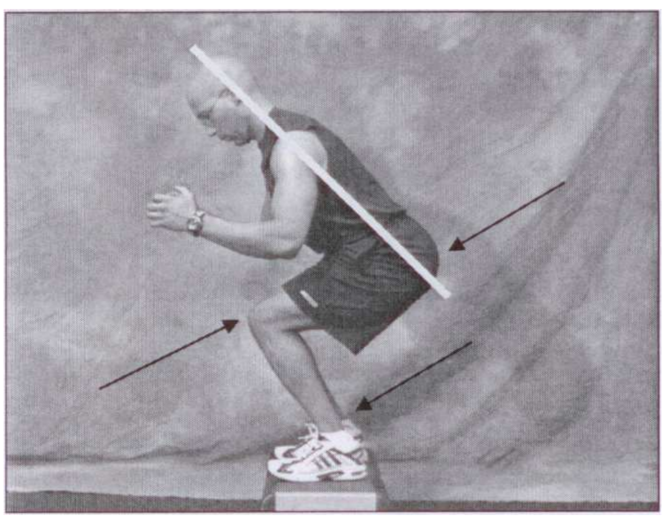
- Small (limited) movements to larger range movements
- Limited duration (ex. 1-2 reps with rest in between each rep) to increased duration (ex. 3-6 reps in rapid succession)
- Body weight to external resistance
- Bilateral to unilateral patterns
- Sagittal plane to multiplanar patterns

Limit high level plyometrics with preadolescents

Due to the high demands of plyometric training, this type of training should not be encouraged in preadolescents. At this point, they have not developed enough base level strength or coordination and they still have open growth plates that can be injured by this level of training. Emphasis should be placed instead on establishing proper base levels of core and general strength, balance and coordination.

Guidelines

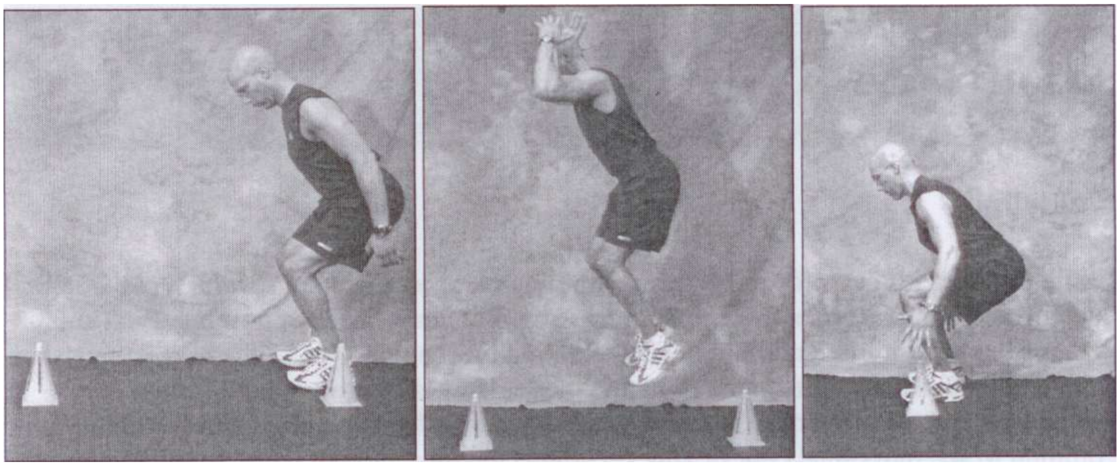
While plyometrics is a safe and effective training method, there are several factors that must be taken into account prior to beginning a plyometric phase of training. First and perhaps the most importantly are the deceleration mechanics. One of the biggest mistakes I see with individuals performing dynamic movements is improper deceleration mechanics. Deceleration must occur with contributions from the hip, knee and ankle. It is common to see individuals not flexing (bending) the hips enough when landing from a jump. It also sounds as if the person is landing hard- usually with a thud. If the individual decelerates properly, there should be a very quiet landing (this rule does not apply with Olympic lifting). There should be relatively equal flexion at the hips, knees and ankles (see arrows). The spine should stay neutral throughout the motion, from acceleration through deceleration (white line). These components do not change whether the jump is performed in the sagittal, frontal or transverse planes or if performed bilaterally or unilaterally.



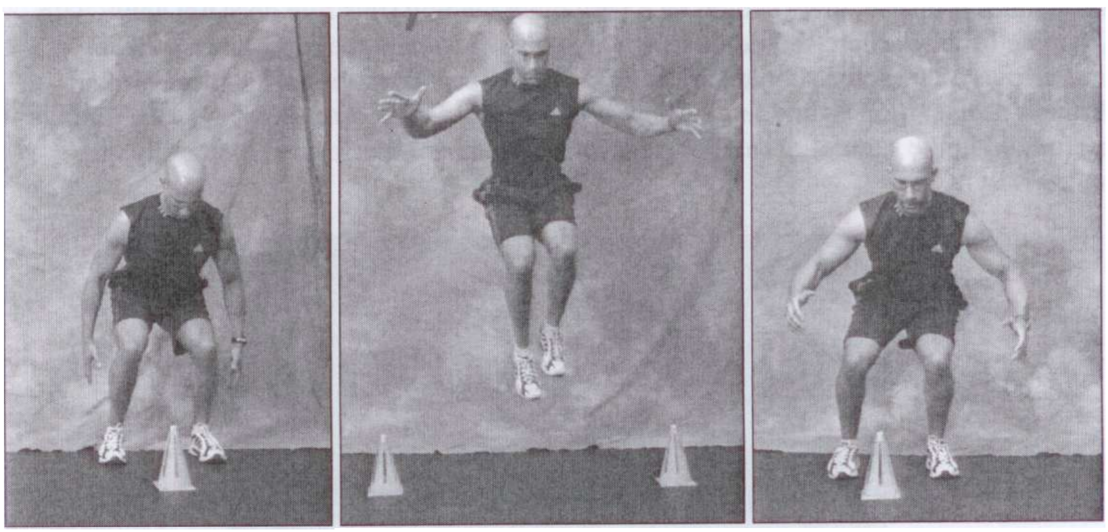
Deceleration mechanics for dynamic jumping

Secondly, plyometric drills should only be used for several weeks at a time since research has shown atrophy of the one joint muscles (joint stabilizers) after a 6 week cycle of jumping. Due to the high intensity on plyometric training, choose one to three movements per session to focus on.

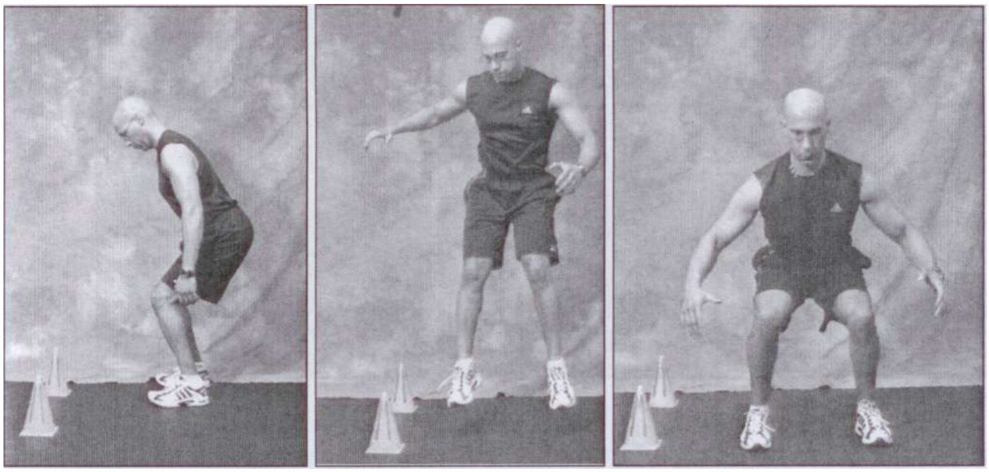
Plyometrics can be performed in multiple planes, unilateral or bilateral and with or without resistance. Maintain proper mechanics throughout all versions.



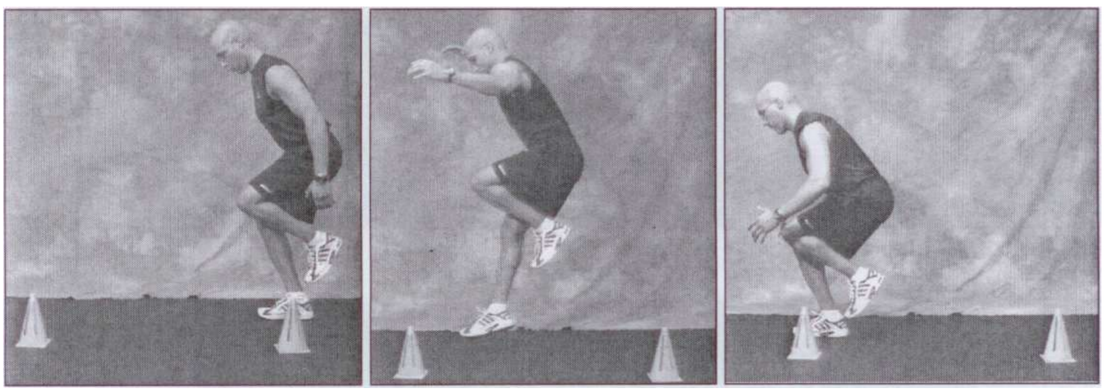
Squat jumps- sagittal plane



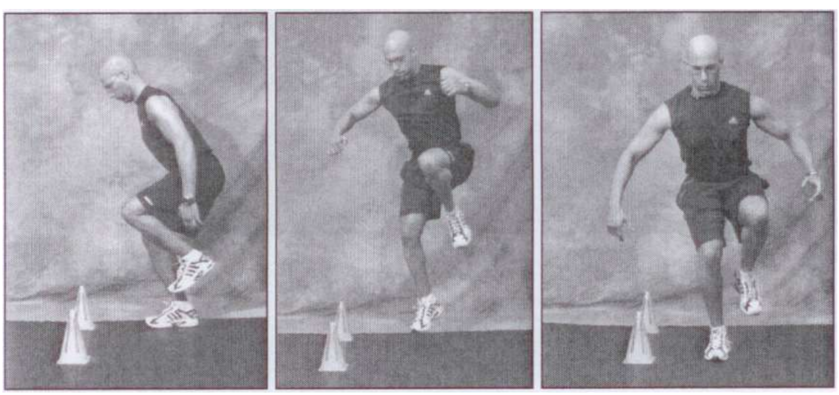
Squat jumps- frontal plane



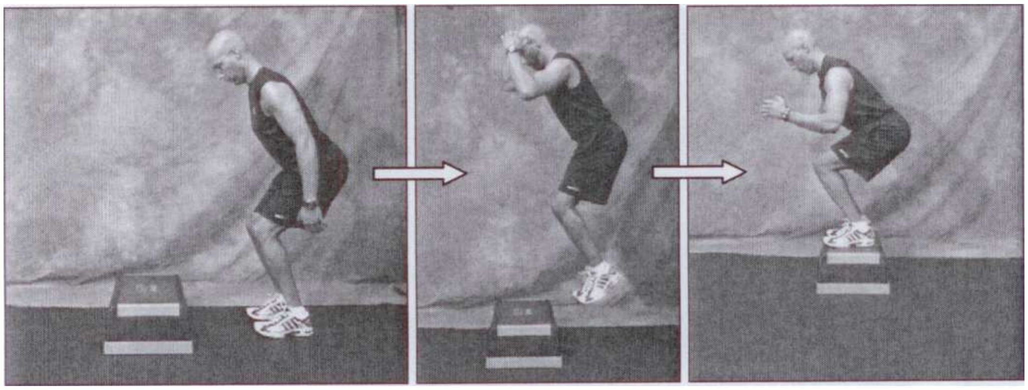
Squat jumps- transverse plane



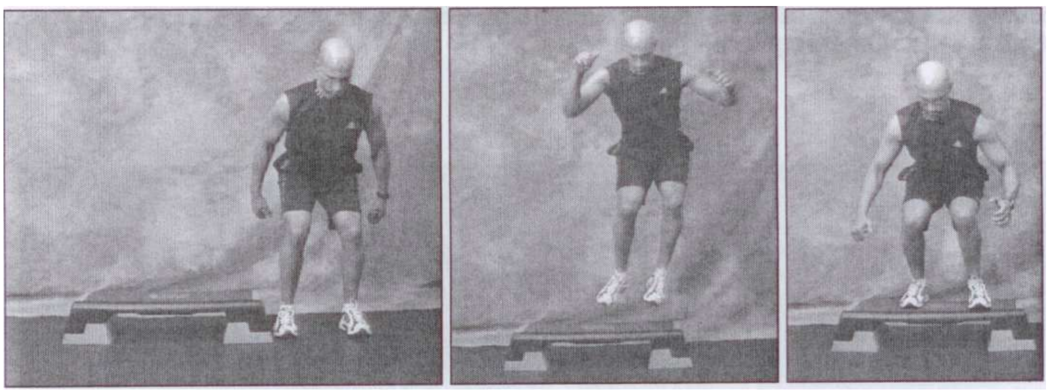
Unilateral squat jumps- sagittal plane



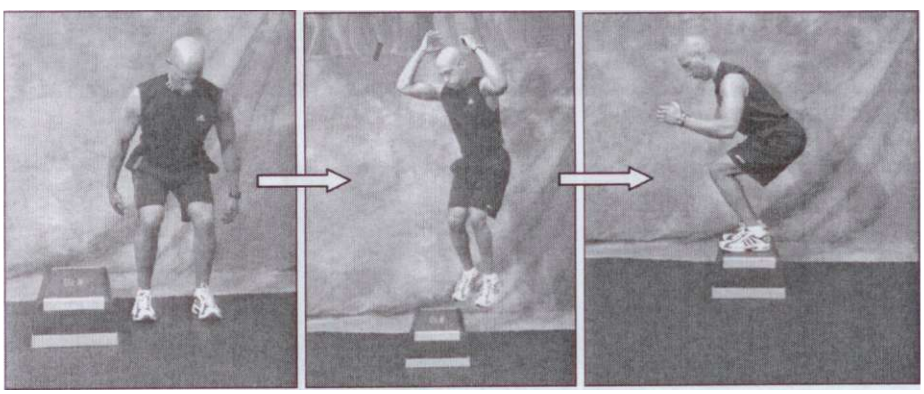
Unilateral squat jumps- transverse plane



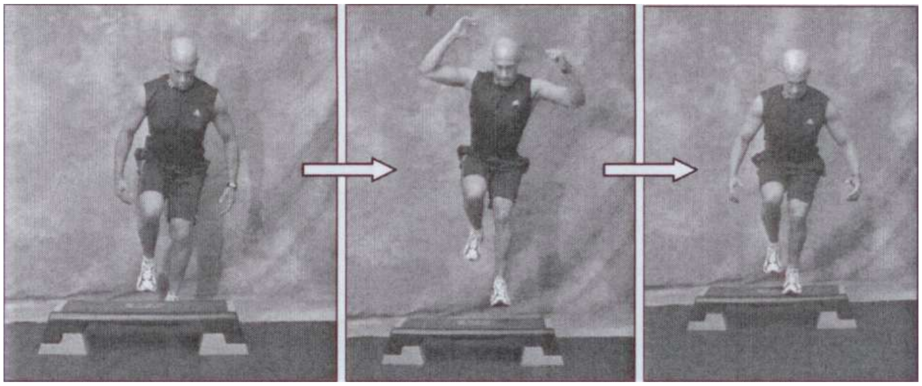
Box jumps- sagittal plane



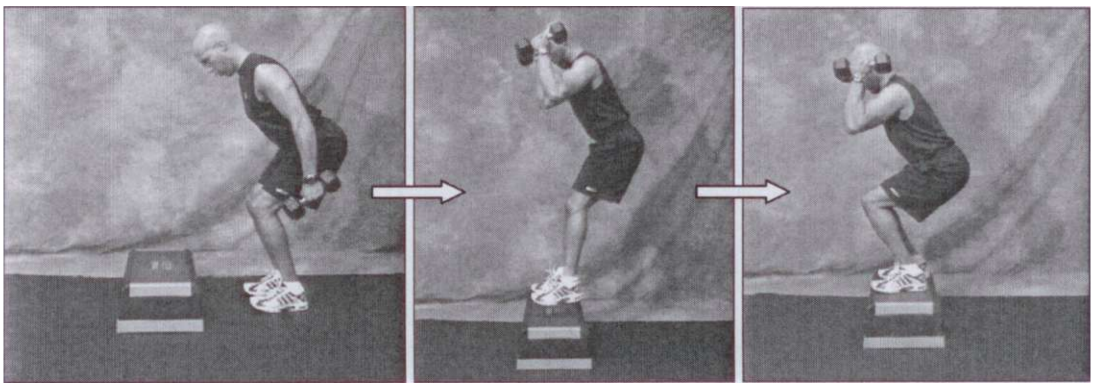
Box jumps- frontal plane



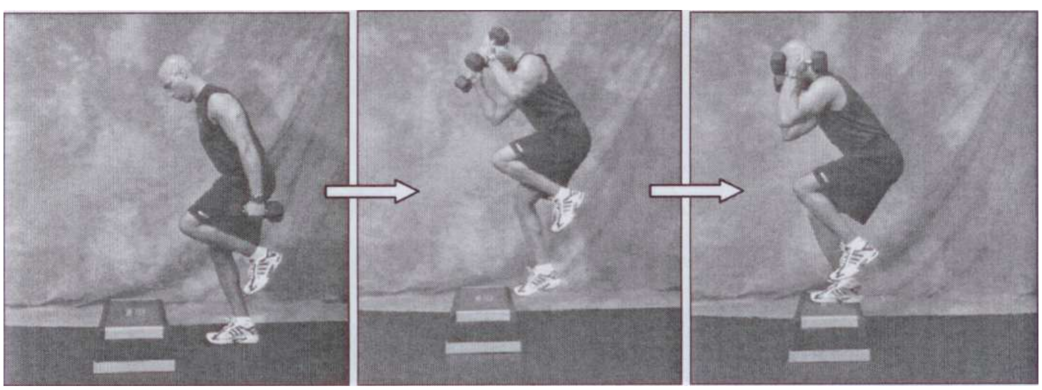
Box jumps- transverse plane



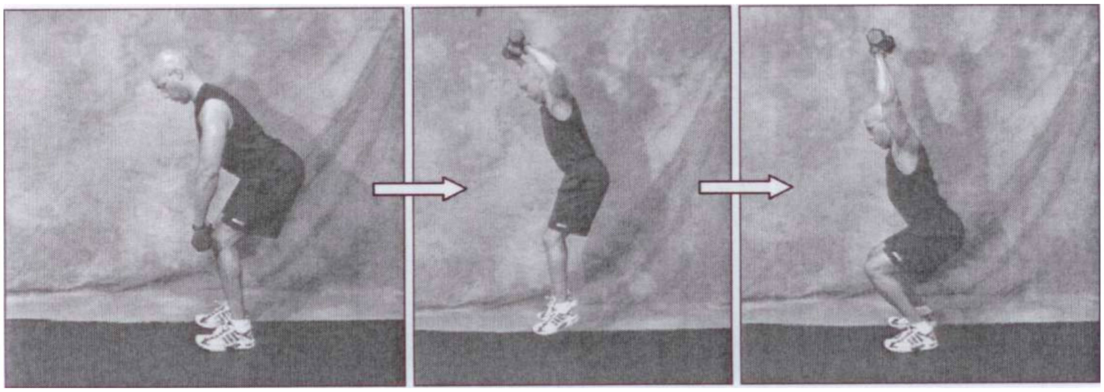
Unilateral box jumps- sagittal plane



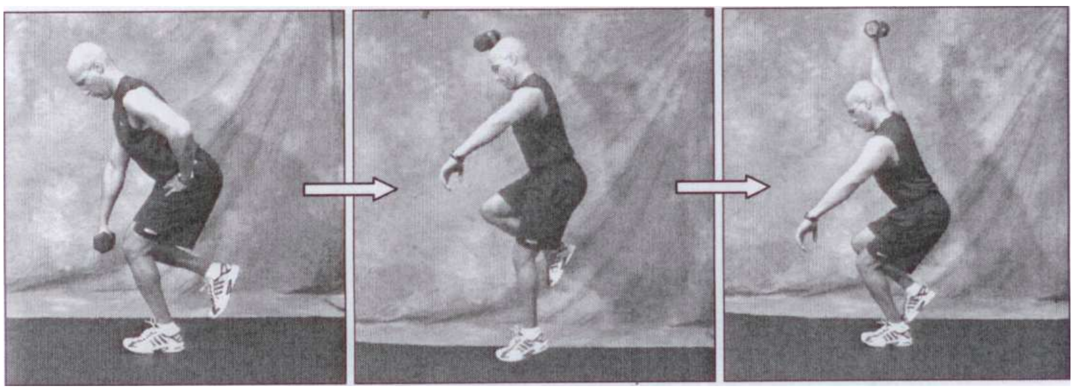
Box jumps with dumbbell clean- bilateral



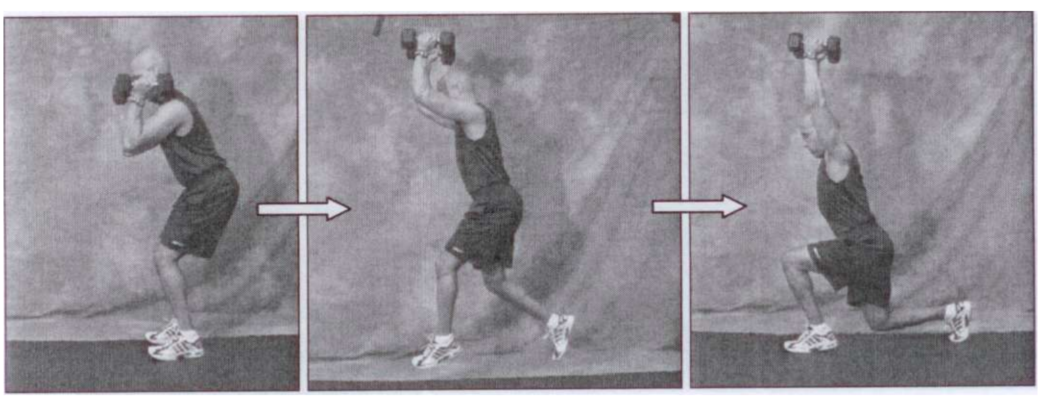
Box jumps with dumbbell clean- unilateral



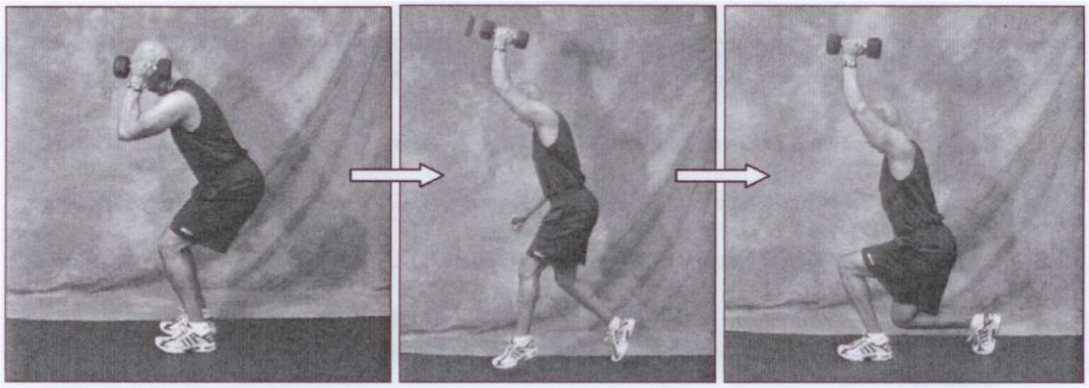
Dumbbell snatch- bilateral



Dumbbell snatch- unilateral



Bilateral dynamic push-press



Unilateral dynamic push-press

CONCLUSION

Improving performance, preventing injuries and progressing exercises appropriately requires a thorough understanding of the hip joint and its relation to the trunk, pelvis and entire lower extremity. This manual has provided a basic overview of the anatomy and biomechanical significance of the hip while including a rational for training and rehabilitation. Developing an optimal program for the client requires addressing muscular imbalances, developing stability through the entire lumbo-pelvic-hip core followed by integrating movement patterns of the hip and lower extremity. This will ensure the greatest success whether the client is an individual recovering from an injury or an advanced athlete looking to improve their performance.

References

1. Bandy, William and Barbara Sanders. *Therapeutic Exercise,* Lippincott Williams & Wilkins, Baltimore, 2001.
2. Bennet, Gayle. What's New, *IDEA Personal Trainer*, IDEA Health & Fitness Inc., San Diego, February 2001.
3. Bennet, Gayle. What's New, *IDEA Personal Trainer,* IDEA Health & Fitness Inc., San Diego, March 2002.
4. Biel, Andrew. *Trail Guide to the Body*, Andrew Biel, Boulder, 1997.
5. Bogduk, Nikolai. *Clinical Anatomy of the Lumbar Spine and Sacrum*, Churchill Livingston, London, 1999.
6. Bomgardner, Rich. *Rehabilitation Phases and Program Design for the Injured Athlete.* National Strength & Conditioning Association, Volume 23, Number 6, December, 2001.
7. Bompa, Tudor O. *Periodization Training for Sports,* Human Kinetics, Champaign, 1999.
8. Chek, Paul. *A Neurodevelopmental Approach to Conditioning,* Vol I-II Videos, Paul Chek, Vista, 2003.
9. Chek, Paul. *Paul Chek on Exercise, Training and Rehab,* Course Handouts, 2001.
10. Chek, Paul. *How to Eat, Move and Be Healthy!,* Chek Institute, San Diego, 2004.
11. Chek, Paul. *Movement That Matters,* Paul Chek, Encinitas, 2000.
12. Chek, Paul. How to be Strong and Beltless- Part 1, Testosterone Magazine, Issue 121, http://testosterone.net/html/body_ 121 back.html.
13. Chek, Paul. How to be Strong and Beltless- Part 2, Testosterone Magazine, Issue 122, http://testosterone.net/html/bodv_ 121 back.html.
14. Chek, Paul. How to be Strong and Beltless- Part 3, Testosterone Magazine, Issue 123, http://tcstosterone.nct/html/bodv 121back.html.
15. Clark, Michael A. *Integrated Training for the New Millennium*, National Academy of Sports Medicine, Thousands Oaks, 2001.
16. Clark, Michael A. and Allen M. Russell. *NASM OPT Optimum Performance Training for the Performance Enhancement Specialist,* National Academy of Sports Medicine, Course Manuel, **2002.**
17. Evans, RC. *Illustrated Essentials In Orthopedic Physical Assessment,* Second Edition, Mosby, St. Louis, 1994.
18. Floyd, R.T. and W.C. Thompson. *Manuel of Structural Kinesiology,* 14th edition, WCB/McGraw-Hill, Dubuque, 1998.
19. Gambetta, Vern. *Building the Complete Athlete,* 6th edition. Course Handouts, Optimum Sports Training, Inc., 2000.
20. Gambetta, Vern. *The Gambetta Method,* Common Sense Training for Athletic Performance, Gambetta Sports Training systems, Sarasota, 1998.
21. Gray, Gary and David Tiberio. *Chain Reaction Explosion*, Course Handouts, Wynn Marketing, Adrian, 2001.
22. Gross, Jeffcry, Joseph Fetto, Elain Rosen. *Musculoskeletal Examination*, Blackwell Science, Maiden, 1996.
23. Kalin PJ, Hirsch, BE. *The origins and functions of the interosseous muscles of the foot.* Journal of Anatomy, June 152: 83-91, 1987.
24. Hall, Carrie M., Lori Thein Brody. *Therapeutic Exercise: Moving Toward Function.* Lippincott Williams and Wilkins, Baltimore, 1999.
25. Hammer, Warren. *Functional Soft Tissue Examination and Treatment by Manuel Methods,* 2nd edition, Aspen Publishers, Gaithersburg, 1999.
26. Hannaford, Carla. *SMART MOVES Why Learning Is Not All In Your Head,* Great Ocean Publishers, Alexander, 1995.
27. Hodges, Paul, Richardson Carolyn, Hides, Julie. *Therapeutic Exercise for Lumbopelvic Stabilization 2nd Edition,* Churchill Livingston, St. Louis, 2004.
28. Hodges, P.W., *The Science of Stability: Clinical Application to Assessment and Treatment of Segmental Spinal Stabilization for Low Back Pain,* Handouts 2003.

29. Hodges, P.W., Richards, C.A. *Inefficient Muscular Stabilization of the Lumbar Spine Associated with Low Back Pain,* Spine, 21 (22): 2640-2650, 1996.
30. Janda, Vladimir. Muscles And Motor Control In Low Back Pain: Assessment and Management, Janda Compendium, Volume 2, OPTP, Minneapolis, 1987.
31. Janda, Vladimir. Muscles And Cervicogenic Pain Syndromes, Janda Compendium, Volume 2, OPTP, Minneapolis, 1988.
32. Janda, Vladimir, Stara, V. Comparison Of Movement Patterns In Healthy And Spastic Children, Janda Compendium, Volulme 1, OPTP, Minneapolis, 1987.
33. Janda, Vladimir. Comparison Of Spastic Syndromes Of Cerebral Origin With The Distribution Of Muscular Tightness In Postural Defects, Janda Compendiulm, Volume 1, OPTP, Minneapolis, 1977.
34. Janda, Vladimir. *Function of Muscles in Musculoskeletal Pain Syndromes*, Course Handouts, 2000.
35. Kendall, FP, EK McCreary, PG Provance. *Muscles Testing and Function*, 4th Edition, Williams and Wilkins, Baltimore, 1993.
36. Lee, Diane. Postpartum Health for Moms. DVD available at www.dianelee.ca.
37. Lee, Diane. *Integrating the Lumbar Spine, Pelvis and Hips,* Course Handouts, 2003.
38. Lee, Diane. *The Pelvis: Restoring Function and Relieving Pain*, Course Handouts, 2003.
39. Lee, Diane. *The Pelvic Girdle,* 3rd Edition, Churchill Livingston, London, 1999.
40. Lee, Diane. *The Thorax: An Integrated Approach,* 2nd Edition, Diane Lee Corporation, British Columbia, 2003.
41. Lee, Diane. *The Thorax: Restoring Function and Relieving Pain,* Course Handouts, 2003.
42. Lee, Linda Joy. *The Integrated Lumbopelvic Core & The Functional Lower Limb: Restoring Stability with Mobility,* Course Handouts, 2004.
43. Lee, Linda Joy. *Thoracic Stabilization & The Functional Upper Limb: Restoring Stability with Mobility,* Course Handouts, 2004.
44. Lee, Linda Joy. *Functional Integration of the Thoraxvic-Core & The Lower Limb,* Course Handouts, 2004.
45. Liebenson, Craig. *Rehabilitation of the Spine,* Williams and Wilkins, Baltimore, 1996.
46. McGill, Stuart. *Ultimate Back Fitness and Performance,* Human Kinetics, Champaign, 2004.
47. McGill, Stuart. *Low Back Disorders- Evidence Based Prevention and Rehabilitation,* Human Kinetics, Champaign, 2002.
48. Michund, Thomas. *Foot Orthosis and Other Forms of Conservative Foot Care.* Thomas Michaud, Newton, 1997.
49. Miser, Carolyn and LA Colby. *Therapeutic Exercise Foundation and Techniques,* 3rd edition, F.A. Davis Company, Philadelphia, 1996.
50. Netter, Frank. *Atlas of Human Anatomy,* Ciba-Geigy Corporation, Summit, 1989.
51. Osar, Evan. *Complete Core Conditioning,* Form and Function Publications, 2004.
52. Osar, Evan. *Complete Hip and Lower Extremity Conditioning,* Forma and Function Publications, 2005.
53. Osar, Evan. *Form and Function,* 2nd edition. Form and Function Publications, 2002.
54. Primal 3D Interacive Series- Complete Human Anatomy, Primal Pictures Ltd., London, 2000.
55. Purvis, Tom. *IDEA Personal Training Congress,* Course Handouts, 2000.
56. Roskopf, Greg. *The Hip Abductors, IDEA Personal Trainer,* IDEA Health & Fitness Inc., San Diego, March 2002.
57. Roskopf, Greg. *The Abdominal Muscles, IDEA Personal Trainer,* IDEA Health & Fitness Inc., San Diego, July-August 2002.
58. Sahrmann, Shirley, *Diagnosis and Treatment of Movement Impairment Syndromes,* Mosby, St. Louis, 2002.
59. Santana, Juan Carlos. *Functional Training: Breaking the Bonds of Traditionalism,* Optimum Performance Systems, Boca Raton, 2000.
60. Santana, Juan Carlos. *Functional Training: Breaking the Bonds of Traditionalism,* Video, Optimum Performance Systems, Boca Raton, 2000.
61. Santana, Juan Carlos. *The Essence of Band and Pulley Training,* Vol I-II Videos, Optimum Performance Systems, Boca Raton, 2000.

62. Santana, Juan Carlos. *The Essence of Body Weight Training,* Vol I-II Videos, Optimum Performance Systems, Boca Raton, 2002.
63. Santana, Juan Carlos. *The Essence of Dumbbell Training,* Vol I-II Videos, Optimum Performance Systems, Boca Raton, 2000.
64. Santana, Juan Carlos. *The Essence of Medicine Ball Training,* Vol I-II Videos, Optimum Performance Systems, Boca Raton, 2001.
65. Santana, Juan Carlos. *The Essence of Stability Ball Training,* Vol I-II Videos, Optimum Performance Systems, Boca Raton, 1999.
66. Shier, David, Jackie Butler, Ricki Lewis. *Hole's Human Anatomy and Physiology,* 8^{lh} edition, WCB/McGraw-Hill, Dubuque, 1999.
67. Stedman's. *Medical Dictionary,* 25^{th} Edition, Williams & Wilkins, Baltimore, 1990.
68. St. John, Paul. *Cervical Stabilization & Atlas Axis Mobilization,* Course Handouts, St. John Neuromuscular Therapy Seminar, 2001.
69. Tibero, David. *Function Junction Newsletter, The Function of the Hip Adductor Muscles,* *vvw h•. xvyn n market ins, com.* 2000.
70. Travell, Janet and David Simons. *Myofascial Pain and Dysfunction, The Trigger Point Manuel, Volume 1 and 2,* 2^{nd} Edition, Williams and Wilkins, Baltimore, 1993.
71. Webster's Ninth New Collegiate Dictionary, Merriam-Webster Inc., Springfield, 1990.

LEARN FROM ONE OF THE LEADERS IN THE FIELD OF FUNCTIONAL MOVEMENT!

COMPLETE HIP AND LOWER EXTREMITY IS THE LONG AWAITED FOLLOW UP TO THE HIGHLY POPULAR FORM AND FUNCTION.

IN THIS MANUAL YOU WILL LEARN:

- How the hip functions as part of the core complex and aids in dynamic stabilization of the body
- To identify signs of overuse and disuse of the muscles of the hip complex
- How the hip aids in overall performance and relates to injury prevention of the low back and knee
- To enhance performance of the hip and lower extremity utilizing safe and effective exercise progressions
- How to rehabilitate or condition your clientele whether they are a beginner or advanced athlete

ABOUT THE AUTHOR

Dr. Evan Osar received his bachelor in science and degree in chiropractic from the Palmer College of Chiropractic. He has also received a diploma in clinical massage therapy from the Soma Institute for Clinical Massage Therapy and national certifications from the National Academy of Sports Medicine and the National Strength and Conditioning Association.

Dr. Osar has dedicated himself to learning not only through self instruction but by instructing others. He holds a faculty position at the Soma Institute for Clinical Massage Therapy where he teaches Kinesiology and Clinical Integration and has authored manuals on functional anatomy and core conditioning. Dr. Osar is one of the founding board members of the International Youth Conditioning Association. He has contributed a chapter on posture and flexibility for the official textbook of the International Youth and Conditioning Association and has helped develop the Level 2 and 3 certifications. Additionally, he presents lectures for personal trainers and other health care practitioners. He is the developer of the Fast and Furious series of seminars focusing on complete core, hip and shoulder conditioning and is currently working on the third edition of Form and Function which he is co-authoring with Dr. Shawn Allen. He currently operates O.S.A.R. Consulting, specializing in chiropractic orthopedics, sports medicine, athletic training and functional rehabilitation. In addition to his work with the public, Dr. Osar treats professional athletes as well as members of the Jofferey Ballet of Chicago and Zephyr dance companies.

OTHER BOOK TITLES BY EVAN OSAR:

Form & Function

The Core

Complete Hip and Lower Extremity

Complete Shoulder and Upper Extremity